ATIONAL POPLAR RIVER WATER QUALITY STUDY

MAIN REPORT

1979

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MAIN REPORT

Prepared by the International Poplar
River Water Quality Board of the
International Joint Commission

1979

International Joint Commission
Washington, D.C., U.S.A.
Ottawa, Ontario, Canada

Dear Sirs:

The International Poplar River Water Quality Board presents herewith its final report to the International Joint Commission on water quality in the Poplar River basin. This report addresses the terms of reference provided in a Directive to the Board from the Commission on September 30, 1977. It expresses the considered opinion of the members of the Board, and is based on studies undertaken by five committees whose reports constitute appendices hereto. A minority report by one of the members of the Board is attached.

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ACKNOWLEDGEMENTS

The International Poplar River Water Quality Board wishes to acknowledge the concerted effort made by the members of the various Committees to the Board. Without their contributions in their various fields of expertise, this study would not have been possible. Particular mention is due to the Committee members appointed by the Saskatchewan Power Corporation and the tribes of the Fort Peck Indian Reservation.

Dr. J.D. Rhoades, U.S. Department of Agriculture, provided recent unpublished information concerning the effects of selected water quality parameters on some irrigated crops. The people of Scobey, Montana provided considerable information on water uses and land use practices.

The contribution of Mr. Gary E. Parker, U.S. Environmental Protection Agency, for his service as secretary to the U.S. Section of the Board during the first part of the study is acknowledged.

Particular mention is due to Mr. Ernest H.G. Cornford, Environment Canada, secretary for the Canadian Section of the Board throughout the study, who assumed full secretarial duties to the Board during the latter part of the study and full responsibility for collation and preparation of the Board report and the printing of all reports and appendices.

Mr. A.E. Weglo, Environment Canada, ably assisted in the preparation and editorial review of all Committee and Board reports.

SUMMARY OF FINDINGS AND CONCLUSIONS

The International Poplar River Water Quality Board (IPRWQB) has undertaken an intensive water quality study of the Poplar River drainage in Saskatchewan and Montana, to assess the water quality effects of the Saskatchewan Power Corporation's (SPC) proposed 600 megawatt, coal-fired power plant at Coronach, Saskatchewan. The Board considered the effects of the plant on surface water quality, ground water quantity and quality, biological resources, and downstream water uses. The study was conducted under the direction of the International Joint Commission which established the Board on September 22, 1977. The organization of the Board, including study committees, and specific directives to the Board by the Commission are found in Chapter 1.

The Poplar River has three main streams, each originating in Canada. They are the West Poplar River, Poplar River and East Poplar River. They converge in Montana, the East Poplar meeting the Poplar River north of the town of Scobey, and the West Poplar joining south of Scobey. The Poplar River flows southward to join the Missouri River near Poplar, Montana, after passing through the Fort Peck Indian Reservation. Cookson Reservoir, the cooling water impoundment for the SPC plant, is located on the East Poplar River about three kilometers upstream from the International Boundary.

In its study, the Board found a great amount of available hydrologic and geologic information concerning the area around the SPC plant. Elsewhere there was a paucity of data, especially on the Montana side of the International Boundary.

Surface water quality records were evaluated at nine locations, using recently acquired data. Long-term water quality baseline data were scarce. Water quality parameters included total dissolved solids (TDS), major ions, nutrients (nitrogen and phosphorus), selected trace elements, boron, dissolved oxygen, pH, temperature, turbidity, selected pesticides and coliform bacteria. The sodium adsorption ratio (SAR) was computed. Of these, TDS and boron are the parameters most likely to be increased by the SPC plant at Coronach, and to result in transboundary effects on crops in Montana. Other parameters such as dissolved oxygen and water temperature could have an effect on the aquatic biota and were considered in this regard. Limited studies conducted on data collected by the Board indicated that the ground water is of marginal quality, with relatively high concentrations of TDS and boron.

Historically, Poplar River water has been used primarily for agricultural purposes. Since the earliest flow records (1931) there has been an upward trend in water use for irrigation, with most of this use in Montana. Municipal use has also increased, but the upward trend is not as great and the total volume used is small compared to irrigation. Most irrigation water is applied to alfalfa, but some is applied to barley and other crops. In this regard, TDS can have the most influence on alfalfa production, while boron can have the most influence on barley production. The effects of TDS and boron on crops are a function of the amount of water applied, previous accumulations of these constituents in the soil, and the soil type. Extensive literature searches and consultations with experts were made to determine these effects in order to derive concentrations of TDS and boron that would be acceptable for existing and future uses of Poplar River water. There is a disparity of professional opinion and scientific findings regarding the effects of both TDS and boron on crop production. In this regard the Board used its best judgement, and has described how it reached its conclusions.

Concerning aquatic biota, the Board recognized a number of chemical and physical constituents that could be harmful. Of particular significance are the spring flows which historically flood and flush the stream channels nearly every two years. Implementation of a proposed water quantity apportionment agreement would, with storage of water in Cookson Reservoir, result in a dampening of spring flows in the East Poplar River, unless releases are made during years of high surface runoff.

In developing water quality objectives to protect downstream uses, the Board considered concentrations of selected water quality parameters at the International Boundary and at the point of use. Again, TDS and boron were the parameters of greatest concern.

The Board determined that any increase in TDS could result in a yield reduction of irrigated alfalfa in the future, when increased acreages under irrigation will place stress on the amount of water available. The Board therefore presented a tabulation of predicted effects for a range of possible increased TDS concentrations in the Poplar River system. Natural concentrations of boron in the East Poplar River are presently higher than ideal for barley production. Thus any development that adds to the boron concentration could further reduce barley yields. Barley is not a major crop in the Poplar River basin, but is grown from time to time on relatively small irrigated plots.

The Board noted several effects of the SPC project: Cookson Reservoir will increase TDS, decrease spring flows, and cause a rise in ground water levels in the vicinity of the reservoir; mine dewatering will add to the TDS and boron concentrations in Cookson Reservoir and a decrease in ground water levels near the mining area; the cooling water system will increase the water temperature of Cookson Reservoir and hence the immediate downstream temperature of the East Poplar River; and the ash disposal system will release contaminants to the East Poplar River.

Proposed ash disposal procedures have the greatest potential for contaminating the East Poplar River. Ash residues from the power plant will be transported to lagoons, and water from the lagoons will be periodically released into the reservoir. There is also the possibility of seepage from the lagoons into the ground and then into the East Poplar River as ground water discharge. The Board recognized the need to reduce leakage from the lagoons into the ground water system and has noted that they could be lined with an impermeable material. While some leachate material will doubtless be sorbed to solid particles as it moves through the earth, some will move in solution and eventually reach the East Poplar River unless lagoon leakage is curtailed.

Fife Lake is a natural storage area upstream from the plant site. This lake can have a high boron concentration, and occasionally overflows into Girard Creek, a tributary to Cookson Reservoir. During years of Fife Lake overflow, Cookson Reservoir could become a repository of water having higher than normal boron concentrations.

Using a computer model, the Board estimated changes in the water quality of Cookson Reservoir, the East Poplar River, and downstream reaches of the Poplar River resulting from the SPC development with emphasis on increased concentrations of TDS and boron. Increases in TDS and boron concentrations will occur, especially during the irrigation season, May through September. For example, boron concentrations will increase fivefold over predevelopment during the irrigation season. A comparison of water quality effects of the SPC plant with the objectives established by the Board, shows that the two-unit SPC plant at Coronach, as presently proposed, would adversely affect future uses of the East Poplar River and downstream by causing increases in concentrations of TDS and boron. In making this estimate, the Board assumed full implementation of the proposed water quantity apportionment agreement. The Board concluded that no other direct water quality effects would adversely affect present and foreseeable uses in the Poplar River system.

In considering other foreseeable developments, the Board recognized that future developments in Montana may also have an impact on Poplar River water quality. These include both industrial and irrigation water use. Although industrial use may include the development of potash reserves in Montana, the water quality effects could not be predicted. Increased irrigation use will doubtless result in depletion of streamflow and an increase of irrigation return water which, in turn, will contribute to increased TDS and boron concentrations in the Poplar River system.

In considering measures for reducing the impact of the SPC plant on water quality, the Board included the following:

1. lining of the ash lagoons;

2. recirculation of ash slurry waters;

3. water softening treatment, or the construction of a storage and diversion reservoir on the Poplar or East Poplar River, upstream from Cookson Reservoir, for a dilution water supply;

4. waste management facilities at the SPC plant designed to minimize all contaminants before they enter Cookson Reservoir, including water from the dewatering wells; and

5. control of overflows from Fife Lake.

SPECIFIC FINDINGS AND CONCLUSIONS

The following items are presented in answer to the Directive to the Board from the International Joint Commission as found in Chapter 1.

1. Factors which affect the existing (pre-Cookson Reservoir) water quality of the rivers in the Poplar River basin are: the natural occurrence of suspended and dissolved erosion products, including occasional overflow from Fife Lake in the upper portion of the system; withdrawal of water for, and return of water from, agricultural irrigation; municipal wastes; and recharge from ground water.

   The effects of the above on water uses result in the following:
   - water used for human consumption must be treated for removal of some naturally occurring constituents (e.g. iron), and
   - the natural occurrence of boron is a factor which presently impairs the potential yield of barley under irrigation in the upper portion of the basin.

2. The biological resources of the Poplar River system, including aquatic plants, invertebrate fauna, fish, waterfowl and mammals (such as ungulates) are not large in quantity and are generally dispersed throughout the system. They are somewhat interdependent and are particularly dependent upon the hydraulic and morphometric characteristics of the rivers. Fish and waterfowl are currently habitat limited. There is a limited recreational fishery, mainly for walleye.

3. Existing major water uses in the Poplar River basin include municipal supply, stock watering, and irrigation. Additional water consumption is due to evaporation. Future water uses will include the above, plus the proposed use of water for the SPC plant at Coronach, Saskatchewan.

4. The proposed water quantity apportionment of the Poplar River system is expected to adversely affect the biological resources of the East Poplar River by reducing the natural effects of the high spring flows which reach 20 m^3/s (700 cfs) on the

average every two years. This will result in increased growth of aquatic vegetation and channel filling, which normally would be removed by the scouring action of the high flows.

A flow release of 20 m^3/s (700 cfs) for a two-day period, occurring in at least 5 years in every 10 year period, would serve to maintain previous habitat conditions.

5. The Board, in evaluating the effects of water quantity apportionment and the SPC plant, developed water quality objectives at the International Boundary for the protection of downstream uses. It was concluded that, except for boron and TDS, the proposed water quantity apportionment and the SPC development are not expected to cause those objectives to be exceeded. The objective for SAR could, however, be exceeded to a slight extent if lime softening treatment of the reservoir is included for scale control without the adoption of ash disposal system mitigation.

6. The effects of increased concentrations of boron and TDS, due to the proposed SPC development, are expected to depend substantially on the nature and extent of future crop irrigation in the Montana portion of the Poplar River system. These effects are described for: (i) present irrigation requirements and practices, and (ii) projected future irrigation requirements and practices. Future water quantity requirements may exceed supply unless a smaller quantity of water is used per application. If less water is used, the adverse effects of boron and TDS in irrigation water would be amplified, because leaching of salts in the plant root zone will be decreased.

   (i) Present Irrigation Requirements and Practices

   Boron: The International Boundary objective for boron to prevent yield reductions of irrigated alfalfa between the International Boundary and the confluence of the East Poplar and Poplar rivers about 26 ha (65 ac) in the irrigation season is 6 mg/L. The seasonal median concentration expected at the International Boundary, due to the SPC development, would reach about 8 mg/L during the irrigation season. As a result of the SPC development and assuming present irrigation requirements and practices, a yield reduction in irrigated alfalfa of about 6 percent is predicted unless mitigation is implemented. No adverse effects due to boron are expected to occur further downstream, under present conditions.

   The International Boundary objective for boron to prevent additional yield reductions of barley irrigated downstream from the SPC development is the value of the natural concentration (median of about 2 mg/L in the irrigation season). The Board determined that irrigated barley is grown only sporadically in the Poplar River basin. Apparently no barley has been grown along the East Poplar River between the International Boundary and Scobey, Montana. In 1978, 18.2 ha (45 ac) of barley were grown just south of Scobey. Considering the effects of the SPC

development, without mitigation, the loss in barley yield, if grown again in the near future at that location, is estimated at $18/acre (1978 U.S. dollars).

TDS The International Boundary objective for TDS, to protect downstream uses, is proposed as 1000 mg/L over a long period (10 years), and 1500 mg/L over any three month period in the irrigation season.

The SPC development is expected to increase TDS concentrations in some months and reduce them in others. The highest median monthly concentration during the irrigation season is predicted to be 1050 mg/L, which is lower than the limiting value for the irrigation season. The longer period requirement is expected to be exceeded, but not sufficiently to significantly affect crop yields, under current irrigation requirements and practices.

(ii) Projected Future Irrigation Requirements and Practices

TDS: Two separate effects of the proposed water quantity apportionment, and the proposed SPC development are expected. The first effect is the elevation of concentrations of TDS as described in (i). As water supplies become inadequate to meet future increased irrigation requirements, present irrigation practices could change, with less water being used per application. Under natural conditions (no SPC development) this would result in yield losses from about 0.8 percent near Scobey to zero near the International Boundary. The effects of increased TDS concentrations due to the SPC development would result in yield reductions of alfalfa ranging from about 1 percent near the mouth of the Poplar River to about 2.7 percent near the International Boundary. These effects would impinge upon larger acreages than are now irrigated, particularly on the Fort Peck Reservation. These future Fort Peck Reservation irrigation developments will, however, require a local impoundment, which is expected to assist in overcoming predicted adverse effects due to increased TDS resulting from the SPC development.

The second effect stems from the increased supply of water due to the proposed water quantity apportionment. This is expected to increase yields. The Board, however, was unwilling to draw conclusions from a comparison of positive and negative effects, because a full cost-benefit study was beyond its terms of reference.

Boron Virtually the same conclusions as for TDS were reached regarding boron, except that the Board was unable to be as specific, due to the inadequate state of knowledge regarding effects of boron under expected future irrigation conditions. These effects for boron are, however, not expected to be as significant as the future effects of TDS.

7. The Board determined that a number of alternatives are possible for mitigation of all expected adverse water quality effects of the SPC development.

8. The predicted increase in acreage to be placed under irrigation in Montana, using waters of the Poplar River system, is expected to cause adverse effects by consumptively using waters available for further irrigation downstream, and by returning poorer quality water to the system. The consumptive use is the most serious effect, as it will detract from the effects of increased water availability due to water quantity apportionment, and will amplify the effects of the increased boron and TDS loadings from the SPC development, as described in 6 above.

9. The SPC development is expected to affect the water quantity of the surrounding aquifers south of the International Boundary by lowering levels by a maximum of 0.7 m (2.3 ft) near the International Boundary south of the mining area, and by raising levels by a maximum of 0.1 m (0.3 ft) near the International Boundary south of Cookson Reservoir.

10. The SPC development is not expected to degrade the water quality of the surrounding aquifers south of the International Boundary.

11. The information available to the Board was inadequate in many important aspects.

    - Baseline surface and ground water data were sparse. Governments had not adequately anticipated the needs for baseline data.
    - The ability of the Board and its committees to evaluate and predict water quality events was hampered by the lack of fully satisfactory prediction models.
    - The state of knowledge of water quality effects on irrigated crops is very inadequate. The development of water quality objectives by the Board, especially for boron and TDS, was made with great reservation, due to the equivocal nature of scientific knowledge on this subject. Clearly more research is needed.
    - Information available to the Board on the nature and degree of probable increases in irrigated acreage was somewhat speculative.
    - Ash and ash leachate characteristics are based on very limited information, and geological data in the ash lagoon areas were insufficient to make predictions of seepage loss with a high degree of certainty.

12. In part, as a result of the findings in 11, the Board concluded that governments should carefully monitor surface and ground water conditions which are subject to the possible influences of the SPC development at Coronach, in order to:
    - verify predicted effects of proposed mitigation, and
    - verify those predicted water quality effects of the SPC development which might not be mitigated.

13. The Board, in addressing its responsibilities regarding the water quality effects of the proposed apportionment of Poplar River system waters, concluded that future water quantity and quality considerations of boundary waters should be examined simultaneously.

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GLOSSARY OF SELECTED TERMS

<u>Activated sludge process</u> - A sewage treatment process in which biological growths mixed with wastewater remove organic matter by oxidation.

<u>Alkalinity</u> - Solutions that have the ability to neutralize acids

<u>Alluvium</u> - Material deposited by flowing water. Alluvial (adj.)

<u>Aquifer</u> - A formation or group of formations, containing unconsolidated or sufficiently fractured permeable material to permit the transfer of water.

<u>Assimilative capacity</u> - The capacity of a water body to assimilate materials.

<u>Baseline Conditions</u> - Those conditions existing in a study area before development.

<u>Bottom Ash</u> - Ash from burnt fuel collected below the boiler. (See fly ash).

<u>Channel Integrity</u> - Property of a river whereby the channel in which flow takes place does not change its location, shape or characteristics with time.

<u>Coliform Bacteria</u> - A group of bacteria commonly found in soil. (See fecal coliform bacteria).

<u>Conservative Constituent</u> - Any dissolved substance that is fairly stable in solution and is not altered in concentration when transported in water.

<u>Diurnal</u> - Occurring over a 24-hour day and night period.

<u>Discharge Area</u> - An area, in terms of groundwater flow systems, where groundwater is released to the surface.

<u>Drawdown</u> - Lowering of the groundwater table surface typically forming an inverted cone shape around the area due to pumping. In terms of surface waters, lowering of the water level, for instance, drawdown of a reservoir by release of water.

<u>Electrical Conductivity</u> - A measure of the ability of material to conduct an electrical current. Similar to specific conductance.

<u>Fecal Coliform Bacteria</u> - A specific type of bacteria used as indicator organisms of contamination of water by human or animal wastes.

<u>Fluvial</u> - Of, or pertaining to, rivers; produced by river action.

Fly ash	- Noncumbustible material suspended along with vapour of volatile elements or compounds in the flue gas stream from burning fuel and consisting of many small glass-like spherical particles (see bottom ash).
Full Service Irrigation	- Includes both sprinkler and flood irrigation.
Hydraulic Conductivity	- Rate at which water may be transmitted through a unit area of an aquifer under standardized conditions.
Hydraulic Gradient	- Change in hydraulic head per unit lengths of flow path.
Hydraulic Head	- The position of a ground-water or surface-water level in relation to some reference elevation.
Hydraulic System	- A water system in which inputs and losses are controlled by the interrelationships between precipitation, evaporation, runoff and groundwater movement.
Invertebrates	- Animals without backbone. Includes aquatic animals such as worms, snails, and flies but not fish.
(Major) Ions	- Those elements most abundant in natural water.
Isopleths	- Lines on a map connecting points of equal value.
Isotope Analysis	- The use of natural radioactive materials to determine the movement or age of water.
JTU	- Jackson Turbidity Unit; a standard unit to express light scattering in water.
Leachate	- A solution containing material that has dissolved from a solid.
Leaching Fraction	- That fraction of water applied to the soil for irrigation which is not used by the plant but which passes through the root zone.
Lime Softening	- The removal of selected elements by the addition of lime.
Macrophytes	- Rooted aquatic plants.
Median	- The middle value in a group of numbers.
Morphometry	- Refers to the measurement of form.
Nutrients	- Those elements that are essential to plant growth; e.g. nitrogen and phosphorus.

Osmosis	- The transport of a solvent (water) through a semi-permeable membrane separating two solutions of different solute (salt) concentration, from the solution that is dilute in solute to the solution that is concentrated.
Outcrop:	- The area over which a geological formation is exposed at the earth's surface.
Periphyton	- Algae attached to solid surfaces (see algae).
Permeable	- Able to transmit water or other fluids.
pH	- A measure of the acidity or alkalinity of water on a scale ranging from 0 (acid) through (7) neutral to 14 (basic).
Physiological Drought	- Occurs when the soil salt concentration is so high that it prevents the uptake of water by plants.
Potentiometric Surface	- A hypothetical surface connecting points to which water would rise in tightly cased wells receiving water from given points in an aquifer.
Raw Water	- Refers to untreated water used for consumption or processes.
Reach (stream reach)	- That part of the course of stream between two identified points.
Recharge Area	- An area where surface waters or precipitation enters the earth to replenish the groundwater system.
Return Flow	- That part of the irrigation water that is not lost by evaporation, taken up by the soil or vegetation and consumed by evapotranspiration, and the return to its source or to another surface water body. The terms also is applied to water that is discharged from industrial plants and recycled in inductrial processes.
Salinity	- Refers to concentration of dissolved materials in water.
Till	- Glacial deposits of mixed clay, sand, and gravel.

LIST OF ABBREVIATIONS FOR UNITS AND CONVERSION FACTORS

(Common symbols for elements and chemical compounds have not been listed)

Abbreviations	Units	Abbreviations	Units
ac	acre	m	metre
ac-ft	acre-feet	mg	milligram
BOD	biological oxygen demand	mg/L	milligrams per litre
C°	centigrade degrees	mi	mile
cfs	cubic feet per second	mL	millilitre
cm	centimeter	mm	millimetre
d	day	m/s	metre per second
dam	decameter	MW	megawatt
F°	Fahrenheit degrees	ppb	parts per billion
FSL	full supply level	ppm	parts per million
ft	feet	RO	reverse osmosis
g	gram	R.O.D.	release-on-demand
gal	gallon	s	second
ha	hectare	SAR	sodium adsorption ratio
hr	hour	SC	specific conductance
Igpd	Imperial gallon per day	SPC	Saskatchewan Power Corporation
Igpm	Imperial gallon per minute	T. Alk.	total alkalinity
IJC	International Joint Commission	TDS	total dissolved solids
in	inch	ton	short ton
IPRWQB	International Poplar River Water Quality Board	tonne	metric tonne
		μg	microgram
JTU	Jackson Turbidity Units	μg/L	micrograms per litre
kg	kilogram	U.S.gpd	U.S. gallon per day
km	kilometer	U.S.gpm	U.S. gallon per minute
L	litre	yr	year
lb	pound		

CONVERSION FACTORS

ac-ft	=	1,233.5 m^3 = 1.2335 dam^3
ac	=	4047 m^3 = 0.4047 ha
C°	=	1.8 F°
cm	=	0.3937 in.
cm^2	=	0.155 in^2
dam^3	=	1000 m^3 = 0.8107 ac-ft
ft^3	=	28.3171 x 10^{-4} m^3
ha	=	10,000 m^2 = 2.471 ac
hm	=	100 m = 328.08 ft
hm^3	=	1 x 10^6 m^3
Igpm	=	0.0631 l/s
in	=	2.54 cm
kg	=	2.20462 lb = 1.1 x 10^{-3} tons
km	=	0.62137 miles
km^2	=	0.3861 mi^2
L	=	0.3532 ft^3 = 0.21997 I. gal. = 0.36420 U.S. gal
L/s	=	0.035 cfs = 13.193 Igpm = 15.848 U.S. gpm
m	=	3.2808 ft
m^2	=	10.7638 ft^2
m^3	=	1000 L = 35.3144 ft^3 = 219.97 I. gal = 264.2 U.S. gal
m^3/s	=	35.314 cfs
mm	=	0.04 ft
tonne	=	1000 kg = 1.1023 ton (short)
U.S.gpm	=	0.0758 L/s

1. INTRODUCTION

1.1 The Setting

The Poplar River basin is situated in the semi-arid region of southern Saskatchewan and northeastern Montana (Fig. 1.1). The basin straddles the International Boundary in the shape of an inverted pear, with the upper third in Canada and the lower third within the Fort Peck Indian Reservation. The Poplar River has three principal tributaries, each originating in Canada. The East Poplar River (East Fork) joins the main stem Poplar River (Middle Fork) in Montana about three kilometres (two miles) north of Scobey, Montana; the West Poplar River (West Fork) joins the main stem approximately 30 km (20 mi) south of Scobey, Montana. The total basin area is 8620 km^2 (3330 mi^2) of which 3150 km^2 (1215 mi^2) are in Canada. The lower 2230 km^2 (860 mi^2) lie within the Fort Peck Indian Reservation.

The Poplar River basin is part of an upland complex composed of the Cypress Hills, Wood Mountain, the Flaxville Plateaus and much of the Missouri Coteau. The topography is level to gently rolling. Four principal terrain types in and adjacent to the study area combine to form a complex physiography. These are (1) widespread rolling uplands underlain by sand, silt, clay, and coal interbedded with sandstone and siltstone; (2) parts of the river valleys and adjacent uplands covered with glacial deposits; (3) gravel terraces; and (4) alluvial river valleys. The main stem Poplar River valley varies in width from about 3 to 6 km (1.9 - 3.7 mi); tributary stream valleys are smaller and narrower. The river valley and the surrounding prairie were originally natural grasslands, but much of the basin has now been transformed into cropland and pasture. Some wildlife inhabits the basin, and several species of fish are found in the pools and deeper reaches of the rivers.

The climate of the basin is continental with cold dry winters, moderately warm wet springs, and warm dry summers. It is an area where water is scarce. Problems related to inadequate water supplies have existed since the area was first settled in the 1880s. At the International Boundary there have been extended periods of very low or no flow on the West Poplar and Poplar rivers. In the East Poplar River flows less than 0.06 cubic meters per second (m^3/s) or 2 cubic feet per second (cfs) occur thirty percent of the time. The average annual precipitation ranges from 30 to 40 centimetres (cm) (12 to 16 inches (in)), about a third of which is snow. Peak spring flows, lasting 10 days to 3 weeks, account for approximately three-quarters of the total annual discharge. These spring flows rapidly decrease to small summer flows and insignificant autumn and winter flows. The total average annual natural flow of major tributaries at the International Boundary is

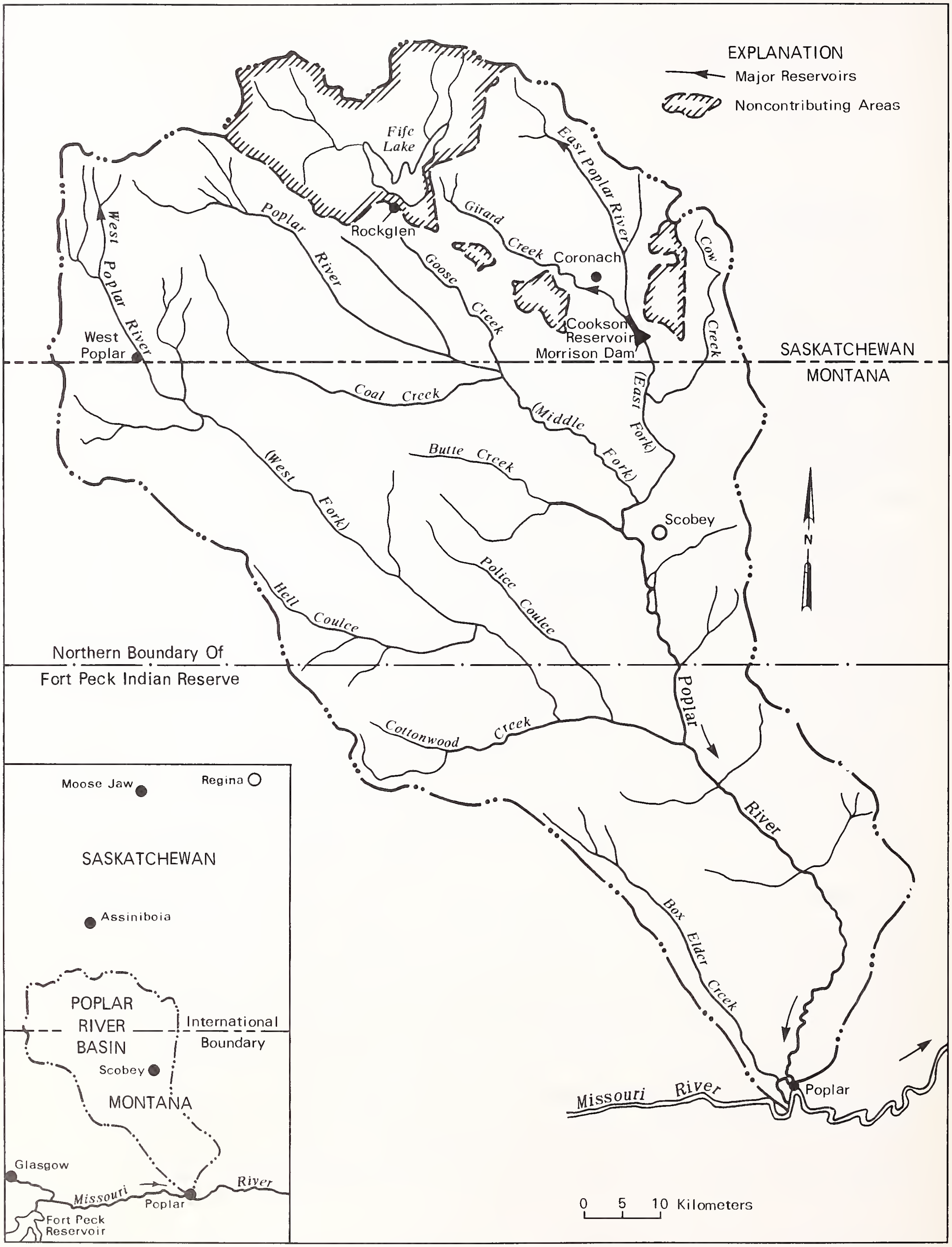

Figure 1.1 Maps of Poplar River Basin, Saskatchewan-Montana.

approximately 42 000 cubic decameters (dam^3) (34,000 ac-ft); at the mouth of the Poplar River at Poplar, Montana, the average annual flow is 115 000 dam^3 (93,000 ac-ft). The region has occasionally been subjected to severe droughts extending to a decade. Development which depends on water resources is limited because water supplies are insufficient, unreliable, and of too poor quality to satisfy many water requirements.

Surface water quality of the basin is strongly influenced by the origin of the water. High flows resulting from snowmelt and spring runoff are of good chemical quality; low summer and winter flows come mainly from ground water of much poorer chemical quality. For example, total dissolved solids (TDS) concentrations are greatest when streamflows are low, when values often exceed 1000 milligrams per litre (mg/L). Other chemical water quality parameters, namely boron and sodium, are at levels that could stress established uses in the basin.

The population of the basin is estimated to be 8000 persons, of which about two-thirds reside in the United States. Except for Rockglen (population 524) and Coronach (300) in Saskatchewan, and Poplar (1,400) and Scobey (1,500) in Montana, the basin is primarily rural. Ranching and the growing of cereal and fodder crops are important to the economy.

1.2 The Problem

1.2.1 Canadian Events

Responding to increasing demand for energy in the Province of Saskatchewan, the Saskatchewan Power Corporation (SPC) determined that adequate coal resources exist in the area just west of Coronach to support a coal-fired, electric power generating plant. Adequate cooling water could be provided by placing a dam on the East Poplar River to form a local storage reservoir on the East Poplar River and Girard Creek.

In March 1972, SPC made application to the Province of Saskatchewan to store and use specific quantities of water from the East Poplar River. In July 1972, the Province reserved 7400 dam^3 (6,000 acre-feet) annually for a five-year period to meet this request.

On September 4, 1974, SPC announced plans for the construction of an electric power plant on the East Poplar River near Coronach, Saskatchewan. On September 11, 1974, a Board of Inquiry into the Poplar River Thermal Generating Project was appointed by the Government of Saskatchewan. In its report of January 1975, the Board of Inquiry concluded that a 300-megawatt (MW) plant at Coronach was economically desirable. It also recommended that the Saskatchewan Minister of the Environment:

> "...appoint a further Board of Inquiry to review the final proposals for mitigation of the environmental effects, to receive public comment on the measures, and to make recommendations respecting the adequacy of the proposed measures."

Further, the Board of Inquiry recommended:

> "...that the Government of Saskatchewan request the Government of Canada to take the steps necessary to achieve an equitable apportionment of the flows of the Poplar River System in order that Saskatchewan can make sound water development plans for this area of the province."

In late February 1975, the Government of Saskatchewan issued SPC an "Authorization to Construct Works" for Morrison Dam on the East Poplar River and a power plant, subject to conditions of the Canada-United States Boundary Water Treaty of 1909. Subsequently, the Government of Canada granted SPC a five-year licence, under the International River Improvements Act, subject to conditions of the Boundary Waters Treaty, as well as compliance with possible future international apportionment agreements.

The major features of the SPC development near Coronach are illustrated in Figure 1.1. Construction of Morrison Dam began on July 22, 1975 and was completed by September 18, 1975, when the filling of Cookson Reservoir began. By April 1978, the reservoir, with a capacity or full supply level (FSL) of 41 166 dam^3 (33,375 acre-feet), had reached an elevation of 751.5 m (2465.5 ft), approximately 1.5 m (4.9 ft) below FSL. Site grading for the initial 300-MW plant began in August 1975, and the foundation was poured in March 1976. Although a commercial start-up date of May 1979 had been planned, a labor strike, and other delays, resulted in a postponement. This 300-MW unit is now scheduled to be operational in March 1980.

In anticipation of environmental concerns noted within the Board of Inquiry's recommendations, all of which had been endorsed by the Government of Saskatchewan, SPC undertook environmental studies which resulted in a Summary Report in September 1977. This report noted an ultimate goal of four 300-MW units (1200 MW), together with a cooling water reservoir and adjacent coal mining operations. It included a specific proposal for one of these units, and summarized expected environmental effects and proposed mitigation measures. On December 15, 1977 the Government of Saskatchewan established a Poplar River-Nipawin Board of Inquiry to review the SPC proposal for a second 300-MW unit at Coronach, as well as a proposal for a hydro-electric generating plant at Nipawin, Saskatchewan. The report of that Board was submitted to the Saskatchewan Minister of the Environment on June 30, 1978. The Government of Saskatchewan endorsed the Board's recommendations of approval for the second 300-MW unit, subject to conditions relating in part to international obligations.

1.2.2 International Events

In the early months of 1975, responding to concern expressed by the Governor of Montana, the United States State Department delivered a note to the Canadian Embassy in Washington regarding transboundary implications of the proposed SPC development at Coronach.

Pursuant to an ongoing Reference (1948) to the International Joint Commission (the Commission or IJC) by the two federal governments, the IJC instructed its International Souris-Red Rivers Engineering Board in April 1975, to study the distribution of surface waters in the Poplar River basin with Cookson Reservoir in place, and to prepare recommendations for the apportionment of the transboundary flows of the entire Poplar River system. The report to governments stemming from that study was provided in mid-1978. In August 1977, resulting in part from the 1975 note to Canada from the United States, and subsequent discussion on the project, the two governments issued a new Reference to the IJC concerning the water quality of the Poplar River basin.

1.3 Reference to the International Joint Commission on Poplar River Water Quality

Following the above events, the governments requested that the IJC study and report upon the water quality of the Poplar River basin (with particular emphasis on the East Poplar River), including the present quality, the factors affecting water quality and its uses, and the consequent effects of: (1) apportionment as recommended by the International Souris-Red Rivers Engineering Board's Poplar River Task Force; (2) a 600-MW thermal power project; and (3) other reasonably foreseeable water uses.

The governments requested that the IJC proceed with these studies as expeditiously as practicable and report to governments no later than December 1, 1978. The IJC was to issue interim reports as appropriate.

1.4 Directive to the International Poplar River Water Quality Board

After reviewing the August 1977 Reference from the two governments concerning the water quality of the Poplar River, the IJC established the International Poplar River Water Quality Board (IPRWQB-the Board), on September 28, 1977. The IJC then issued a "Directive to the Board" which requested that the Water Quality Board undertake the investigations and studies necessary to advise the Commission on all matters which it must consider in making its reports to governments. The Board was requested to examine into and report upon the water quality of the Poplar River, including the transboundary water quality implications of a 600-MW thermal power station, giving consideration to chemical, physical, biological, economic and social factors. The study was to include:

1) the present state of water quality, including fluctuations thereof with particular emphasis on the waters of the East Poplar River;

2) the factors, both natural and man-made affecting existing water quality, and their effects on water uses;

3) the nature, location and significance of fisheries and wildlife dependent on the waters of the Poplar River;

4) the nature and location of existing and reasonably foreseeable water uses;

5) the effects on present water quality and consequent effects on the uses identified in paragraphs (3) and (4) above, which would result from the following, both separately and cumulatively:

   (a) changes in the flow regime of the Poplar River if apportionment of the waters of the Poplar River is made as recommended by the International Souris-Red Rivers Engineering Board's Poplar River Task Force in its report of February 27, 1976, or as the Commission may otherwise recommend;

   (b) the thermal power station of the SPC and ancillary facilities, including coal mining;

   (c) implementation of other reasonably foreseeable developments in either country.

6) significant transboundary impacts of the SPC's thermal power station and ancillary facilities, including coal-mining, and of reasonably foreseeable developments in either country on the water quality and water level in the surrounding aquifers;

7) such other matters as the Commission may indicate to the Board during the course of the study.

The Board was also asked to advise on mitigation measures which could be taken to avoid or relieve any adverse transboundary effects which could stem from those concerns noted in items 5) and 6) above, and to indicate the approximate costs of such measures.

The Board was requested to submit a proposed plan of study by November 1, 1977 outlining the phases of study, their estimated time of completion, and the costs involved. It was further requested to report to the Commission on December 1, 1977 to advise on the status of the SPC project and what effect, if any, the work in the project could have on the Board's study. Interim reports noting progress achieved and issues of concern were also required to keep the Commission informed. The final report of the Board with appendices was requested by September 1, 1978.

1.5 Organization of Board and Committees

Members of the Board, four from each country, were appointed by the IJC and requested to attend public hearings in Scobey, Montana and Regina, Saskatchewan, November 2 and 3, 1977. Subsequent to the hearings, the IJC discussed with Board members the "Directive to the Board" and relevant questions raised at the hearings and directed the Board to prepare and

submit a Plan of Study. Board members were advised that they and any members of Committees who might be appointed must serve in a personal and professional capacity under the direction of the Commission and not as representatives of their employers.

The Board members met immediately following these discussions to review the Commission's Directive, to define the study requirements, and to structure an organization to meet them. Six areas of study were identified and Board members were appointed to investigate work plans and to recommend a nucleus of appropriate expertise for each area. These included: 1) Water Uses; 2) Water Quality Objectives; 3) Surface Water Quality; 4) Ground Water Quality and Quantity; 5) Aquatic and Terrestrial Biology; and 6) Plant, Mine and Reservoir Operations. Draft terms of reference for committees to address these study areas were reviewed by the Board Co-Chairmen on November 28, 1977. Study Groups 1) and 2) were combined to consider Uses and Water Quality Objectives. On December 13 and 14, 1977, the Board ratified these terms of references, formed committees to address them, and developed a draft plan of study to answer the Directive from the IJC. The plan of study, including the committee structure, membership and work plans, was submitted to the IJC on January 18, 1978 and received final approval in February 1978. The development of this plan demonstrated the need for a more realistic completion date of January 1, 1979. Subsequent problems in obtaining baseline data necessary for the work of the Board, and other delays, required postponement of the reporting date even further, to May 1, 1979. Further delays in finalizing committee studies and preparation of reports, and delays in Board report preparation necessitated postponement of the reporting date to July 1, 1979. The cost of the study is estimated at three-quarters of a million dollars.

1.6 Plan of Study

The plan of study developed by the Board consisted essentially of the plans developed for each of its committees, together with the mechanisms for intercommunication and the ultimate production of the Board's final report. The basic tasks of each of the five committees are summarized below.

The Surface Water Quality Committee - To determine the present state of water quality in the basin, including fluctuations in water quality; to determine the factors, both natural and man-made, affecting water quality and their effects on water uses; and to predict those water quality changes anticipated in the future from pollution sources and hydrologic modifications (Appendix A).

The Ground Water Quantity and Quality Committee - To determine the present and future ground water quantity and quality in the Poplar River drainage basin on both sides of the International Boundary, including the area around the power plant, the area proposed for coal mining, and the area above and below the reservoir (Appendix B).

The Biological Resources Committee - To compile background and baseline data related to biological and ecological factors; to evaluate the effects of water quality and quantity on the biological resources and their environment in the Poplar River system; and to compare these effects under the water quality conditions and stream flow regime, with and without operation of the power plant and reservoir (Appendix C).

The Water Uses and Water Quality Objectives Committee - To review and report on present and reasonably foreseeable uses of water, including municipal and domestic water supplies, stock watering, agricultural irrigation, industrial water needs, maintenance of fish and wildlife, and recreational uses; to examine the water quality criteria required to support the identified uses; and to develop and recommend water quality objectives to be met at the International Boundary to protect the most sensitive identified downstream uses; to examine and report on the effects of projected water quality on future uses (Appendix D).

The Plant, Mine and Reservoir Operations Committee - To identify the influences on water quality resulting from construction and operation of the plant, mine, reservoir and related facilities; and to gather and evaluate design information, data on existing and expected operations and environmental controls, and remedial practices (Appendix E).

A comparison of the questions directed to the Board and the tasks of the committees demonstrates the interdependence of the committees and the need for close cooperation and communication. This was achieved in part through periodic workshops, involving all committees and the Board. Also, the development of committee reports was organized for compatibility with the structure of the Board's final report.

In preparing its report, the Board reviewed the committee reports and, as noted above, included them as appendices. In some instances, however, data provided in the committee reports were later revised by the committees because of information received after final report preparation. In cases where discrepancies exist between data in appendices and in the Board's report, data in the Board's report should be considered as the most recent.

It will be noted that agreement within committee reports was not always unanimous. The report of the Water Uses and Water Quality Objectives Committee was endorsed by seven of nine committee members and contains two minority attachments, one of which was signed by three of the members. The Board, in all cases, used its discretion in developing its final conclusions and does not necessarily endorse all the findings and conclusions reached by committees.

2. THE POPLAR RIVER DRAINAGE BASIN

2.1 The Drainage System

The Poplar River has three principal tributaries, each originating in Canada, where they are known as the East Poplar, the Poplar and the West Poplar Rivers; in the United States, they are designated as the East Fork, Middle Fork, and West Fork of the Poplar River. The Canadian designations are used exclusively throughout this report.

The Poplar River and its tributaries are typical low-gradient prairie streams. Their natural flow patterns are characterized by high spring and low summer flows. Flow in the basin is generally towards the south and southeast to the point where the Poplar River joins the Missouri River near Poplar, Montana. At Poplar, the long-term average annual flow is 3.8 m^3/s (134 cfs). Physically, the Poplar River and its tributaries are made up of sequences of alternating large pools and shallow riffles. Gravel is the dominant streambed material in the riffles, whereas sand, silt and mud bottoms predominate in the pools.

Within the Poplar River basin, the East and West Poplar Rivers join the Poplar River at points 3 km (2 mi) north and 30 km (19 mi) south, respectively, of Scobey, Montana. The three tributaries of the river receive water from a number of smaller streams in Saskatchewan and Montana, of which Girard Creek has the greatest importance in this study. Girard Creek lies wholly in Saskatchewan, transects the proposed SPC strip-mining area, and flows into Cookson Reservoir on the East Poplar River about 5 km (3 mi) north of the International Boundary. Other secondary streams of some interest for this study include Goose and Coal creeks, both of which cross the International Boundary, and Butte Creek located entirely in Montana.

Natural drainage within the Poplar River basin has been modified by the addition of numerous reservoirs. The largest is Cookson Reservoir with a storage capacity of 41 166 dam^3 (33,375 ac-ft) which was constructed by SPC to provide cooling water for the Coronach power plant. Cookson Reservoir receives water from both the East Poplar River and Girard Creek and discharges water to the East Poplar River downstream from its impoundment structure, Morrison Dam. The next three largest reservoirs in the basin have a combined capacity of only 2270 dam^3 (1840 ac-ft).

The Poplar River basin in Saskatchewan contains a number of internal drainage areas that during most years do not contribute to the flow of the Poplar River system. The largest

and most important is the Fife Lake drainage area of about 414 km^2 (160 mi^2) lying at the extreme northern end of the basin. The outlet from Fife Lake is dammed. Historically, overflow to Girard Creek has only occurred on an average of about once every ten years.

2.2 Soils and Geology

There is a relative abundance of detailed information on soils and geology for the Coronach and adjacent areas of the Poplar River basin. Elsewhere in the basin such information is much more sparse. This uneven distribution reflects the concentration of data-gathering activities in the SPC plant, mine and reservoir areas and in the immediately surrounding regions. In particular, the abundance of information on soils and geology is a consequence of the extensive subsurface exploration program that was required for evaluation of the coal resources in the Coronach area.

Soils in the Poplar River basin range from sandy and clay loam in the uplands to more fertile alluvial soils in the river valleys. Soils at the Coronach mine site consist mainly of Chernozemic Brown soils with light-brown to grayish-brown surface horizons with a relatively low organic matter content. Some minor Gleysolic soils are also found but are confined to shallow local depressions and slough localities. These soils were derived from glacial till and from underlying bedrock; they are relatively thin and moderately calcareous.

A brief description of geologic units important to this study is presented in Table 2.1 and a generalized geologic map of part of the upper Poplar River basin is shown in Figure 2.1. The table shows that the names assigned to the geologic formations in Canada are different from those assigned in the United States. Canadian names are used exclusively in this report.

The deepest bedrock formation shown in Table 2.1 is the Bearpaw Formation. It is a thick sequence of marine silts and clays and is much less permeable than the overlying sediments. Because of this low permeability and because the Bearpaw Formation is not exposed at the surface in the general area of the East Poplar River basin, it may be considered to act as an effective lower boundary to ground water flow in the overlying sediments in this area.

Three bedrock formations, the Frenchman, the Ravenscrag and the Wood Mountain Formations, in ascending order, overlie the Bearpaw Formation. The Frenchman is composed primarily of sand and silt and, like the Bearpaw, is laterally continuous throughout the East Poplar River basin but is not exposed at the surface. The Ravenscrag and the Wood Mountain, on the other hand, have been eroded by stream action in parts of the Poplar River basin and are exposed, for example, along the valley slopes of Goose Creek.

The Ravenscrag Formation is conveniently divided into upper and lower portions separated by the Hart Coal Seam. The lower portion is composed mostly of silt and clay with a lesser

Table 2.1 GEOLOGIC FORMATIONS IN THE POPLAR RIVER BASIN

Formation (Saskatchewan Nomenclature)	Formation (Montana Nomenclature)	Range in thickness m (ft)	General Character
Alluvium	Alluvium	0-55 (0-180)	Floodplain deposits of gravel, sand, and silt
Glacial deposits	Glacial deposits	0-30 (0-100)	unconsolidated till, lake deposits, and glacial melt-water
Empress Group	Wiota Gravels	0-3 (0-10)	Gravel
Wood Mountain Formation	Flaxville Formation	0-30 (0-100)	Sand and sandy gravel
Ravenscrag Formation, including Hart coal seam	Fort Union Formation	50-245 (165-800)	Sandstone, siltstone, clay and lignite
Frenchman Formation	Hell Creek Formation Fox Hills Sandstone	40-75 (130-240)	Sandstone, siltstone, and shale
Bearpaw Formation	Bearpaw Shale	335-365 (1100-1200)	Shale and minor sandstone beds

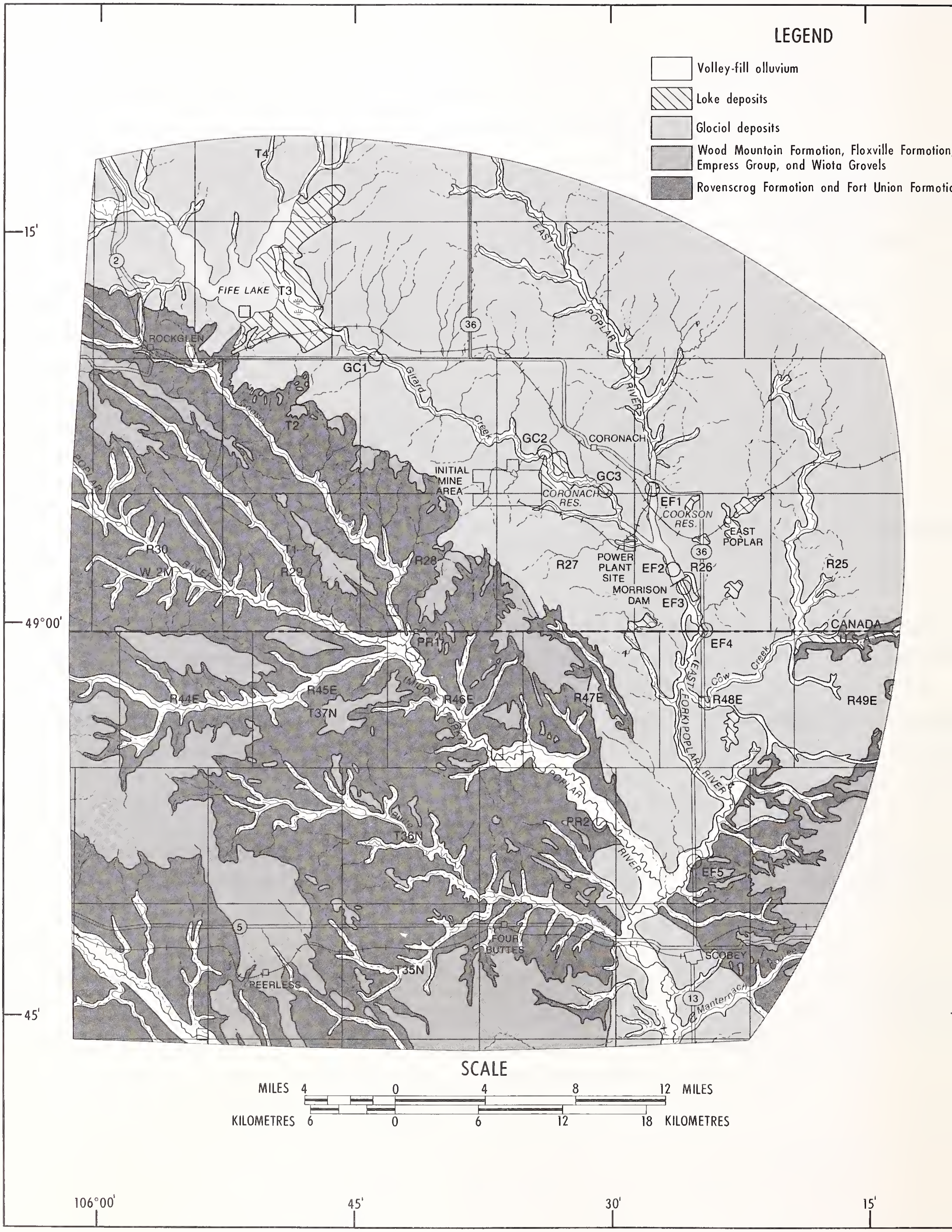

Figure 2.1 Geologic map, upper Poplar River Basin, Saskatchewan and Montana

sand component. The upper portion is similar but contains on the average somewhat coarser material. The Hart Coal Seam will provide the energy supply for the SPC power plant operation. It is used as an aquifer in the Coronach area and is particularly permeable wherever it has been extensively fractured. The Hart Coal Seam has been eroded away within the valleys of both Goose and Girard creeks.

The Wood Mountain Formation is composed of sand and gravel with lesser silt and clay beds. Erosion has left these deposits primarily in upland areas, for example, along the crest of the height of land separating Girard and Goose Creeks. The Wood Mountain Formation is exposed along the valley wall of Goose Creek but is covered by a mantle of glacial deposits to the northeast in Girard Creek valley.

Surficial deposits overlying the bedrock formations include the Empress Group, glacial deposits, and present-day alluvial deposits. The Empress Group comprises sediments deposited on the bedrock surface before the first glaciation in the area. They are primarily stream-deposited sands and gravels but also include materials moved down slope from upland areas by the action of gravity and overland erosion. They are found directly overlying bedrock in the lower-lying portions of Goose Creek and Girard Creek valleys and have wide areal extent in these areas.

The margin separating ice-free from ice-covered areas during the period of glaciation corresponds roughly to the present position of Goose Creek. Glacial deposits, composed principally of till, lie to the northeast of this margin and form a thin mantle over most of the East Poplar River basin.

Present-day alluvium includes loose unconsolidated materials eroded from the adjacent uplands and deposited within the valleys to form the valley floors. These deposits are commonly called valley fill. Similar materials are also found sloping down onto the alluvium from the adjacent valley walls. Lake sediments are concentrated around Fife Lake and other small closed depressions with internal drainage in the extreme northern part of the East Poplar River basin.

2.3 Natural Factors Affecting Water Quality

Natural factors affecting water quality in the Poplar River basin are, for the most part, similar to those that influence water quality in other prairie basins in southern Canada and northern United States.

Precipitation falling on the Poplar River basin is the primary source of the water flowing in its rivers and streams. Some of the precipitation reaches the stream network by overland flow and some by a variety of subsurface routes. Both of these contributions to streamflow are more mineralized than the precipitation from which they originated but the ground water contribution undergoes a much greater quality change. This quality change is

a consequence of longer flow paths, slower flow velocities and the enhanced opportunities that are provided for chemical changes during flow through, and intimate contact with, a variety of permeable subsurface materials.

Surface water quality in the Polar River basin varies seasonally and is strongly influenced by flow. TDS concentrations are greatest when streamflows are lowest. During these low flow periods, streamflows are maintained by ground water. As flows increase, a greater proportion of the total volume is provided by surface runoff and the water becomes less mineralized resulting in a lower TDS concentration. The highest annual flows occur during the spring runoff period when dilution from snowmelt leads to the greatest reduction in the concentration of TDS.

Unlike surface waters, most ground waters usually do not display seasonal variations in chemical properties. Exceptions may occur in the case of shallow alluvial aquifers that regularly exchange waters with nearby rivers and streams. Data for such aquifers in the Poplar River basin are not adequate to demonstrate any seasonal variations. Ground water chemistry depends in part on the chemical equilibrium established between the ground water and the permeable material through which it flows; it also depends on its position within the ground water flow system. Thus, ground water flowing downward through a particular formation will display a different chemistry than ground water flowing upward into the same formation from a deeper part of the flow system. Ground water, as it flows through the subsurface, has its quality affected by chemical reactions with soil and geological materials. The action of bacteria may also influence chemical quality. The product of these processes in the Poplar River basin is a ground water high in sodium bicarbonate and with a relatively high TDS concentration.

The factors outlined above that affect water quality in the Poplar River basin are, as already suggested, the same as those influencing water quality in other prairie basins. The Poplar River basin, however, does possess one exceptional hydrologic feature not characteristic of other prairie basins, Fife Lake. Occasional overflow from Fife Lake can give rise to dramatic water quality changes since its waters are consistently more highly mineralized than other surface waters in the area. These changes will be observed first in Girard Creek and Cookson Reservoir but they may ultimately exert some influence downstream.

2.4 Baseline Surface Water Quality Conditions

The surface water quality record for the Poplar River basin is not extensive (See Appendix A). A few data were collected during the 1950s and 1960s but the great bulk of the information has been collected since 1974. The period of flow record fortunately includes two high-flow (1975, 1976) and two low-flow (1973, 1977) years so that the available water quality data can be assumed in most cases to be reasonably representative of a wide range of possible natural flow conditions. An exception is the case of one sampling station on

the West Poplar River at the International Boundary where it has been determined that high-volume spring flows have not been sampled sufficiently to ensure that water-quality characteristics are reasonably well established.

The estimation of natural surface water quality for the East Poplar River basin also presents some difficulty. In this case there are three factors that tend to distort a straightforward interpretation of available data: 1) the 1975 and 1976 Fife Lake overflows; 2) the impoundment of water in Cookson Reservoir beginning in 1975; and 3) the diversion of water pumped from the Hart Coal Seam into Girard Creek beginning in 1976. All three represent perturbations of the "natural" hydrologic regime in the East Poplar River basin. "Natural" in this context implies not only the absence of any SPC development but also a year in which there is no overflow from Fife Lake. As has already been stated, this last condition occurs about nine years in ten. The water quality effects of these three perturbations will be most pronounced for the East Poplar River but will also persist to a lesser degree downstream from its confluence with the Poplar River.

Surface water quality records have been collected and evaluated at nine locations, two on the East Poplar River, four on the Poplar River, two on the West Poplar River and one on Cookson Reservoir (Figure 3.2). On each river, one station was located at the International Boundary; the other stations included Cookson Reservoir after closure of Morrison Dam; stations near Bredette, Montana, on the West Poplar and Poplar Rivers; a station near Scobey on the East Poplar River; and stations near Scobey and Poplar, Montana on the Poplar River. Water quality records were available for the East Poplar River station for periods both before and after closure of Morrison Dam.

The water quality parameters that were considered include TDS, major ions, nutrients (nitrogen and phosphorus), boron, dissolved oxygen (DO), pH, temperature, turbidity, selected trace metals, selected pesticides and coliform bacteria. Information on all or most of these parameters was available at all stations. Pesticide data were available only for the International Boundary stations.

2.4.1 Total Dissolved Solids (TDS)

Surface water quality in the Poplar River basin is strongly influenced by streamflow. During low flows, TDS usually exceeds 1000 mg/L, whereas during snowmelt period in the spring, TDS levels are then commonly in the 600 to 800 mg/L range. Closure of Morrison Dam has altered the seasonal TDS concentration at the East Poplar River sampling stations. The percentage variation in seasonal median TDS levels is less in Cookson Reservoir than at the East Poplar River International Boundary station prior to dam closure and there has been an even greater reduction in percentage variation (to 10 per cent or less) at the International Boundary station. The general pattern of TDS changes, however, remains unaltered. The low median concentrations at the International Boundary and Cookson Reservoir stations occur during the spring season followed by increased concentrations in the summer, autumn and winter.

Considering the International Boundary stations, the highest seasonal median TDS concentrations are now observed at the East Poplar River station. The lowest values are those at the Poplar River boundary station. Prior to closure of Morrison Dam, East Poplar River TDS concentrations during the spring season were lower than those observed at the other two boundary stations. The change reflects the post-closure retention of snowmelt flood waters in Cookson Reservoir.

The concentrations increase downstream from the headwaters and vary seasonally. Observed monthly median TDS concentrations range from about 450 to about 1200 mg/L at the International Boundary stations; the corresponding values at the Poplar River station near Poplar, Montana are in the 700 to 1500 mg/L range. The lowest seasonal TDS values are observed during the spring at most stations while autumn and winter median values range from about 25 to about 100 percent larger than the spring median concentrations. The relative lack of seasonal variation at the East Poplar River boundary station has already been mentioned. Because of the scarcity of observed data, computer simulation was used to estimate median monthly values for a 43 year period. For the East Poplar River boundary station, this produced a range of values from 250 to 1500 mg/L.

2.4.2 Major Ions

The dominant cation in Poplar River basin surface waters is sodium and the dominant anion is bicarbonate. They are generally three to ten times more abundant than the next most common cations (calcium, magnesium) and anion (sulfate), respectively. Median seasonal chloride concentrations are very low (15 mg/L or less) at most of the sampling stations. At the station near Poplar, Montana, however, chloride ranges from 46 to 200 mg/L during the year. Median seasonal sodium concentrations tend to be somewhat higher (240-375 mg/L) at the Poplar, Montana station than elsewhere in the basin (69-340 mg/L). The basin-wide high sodium concentrations, which contribute to sodium adsorption ratios (SAR), are currently close to or greater than 5 mg/L throughout the basin, except at the East Poplar and Poplar Rivers at the International Boundary where they are about 4 mg/L.

Variations in absolute concentrations were examined by comparing concentrations expressed in mg/L; variations in relative abundance were examined by comparing concentrations expressed in milliequivalents per litre. The first comparison indicated that the concentrations of bicarbonate and sulfate vary seasonally throughout the basin in much the same way as does TDS; no similar variation was evident for any other of the major ions. At most of the sampling stations, the data available were insufficient to carry out the relative abundance comparison. Where it was possible, the results indicated that anion concentrations remained relatively constant throughout the year. There was, in contrast, some suggestion of seasonal variation in cation ratios. In particular the relative abundance of calcium often increased while sodium decreased during the winter or spring season.

2.4.3 Other Water Quality Parameters

The existing data base for *nutrients* - nitrogen and phosphorus, contains analytical results based on a variety of laboratory techniques. This fact introduces difficulties into the comparison of data from different sources and tends to complicate the determination of seasonal or regional variations in nutrient concentrations. The highest nutrient concentrations occurred during spring or summer. During these periods median seasonal total nitrogen and total phosphorus range from 1 to 2 mg/L and from 0.05 to 0.3 mg/L respectively. Nutrient levels are particularly high in Cookson Reservoir where the seasonal medians for total nitrogen and total phosphorus are 1.06 to 1.93 and 0.14 to 0.28 mg/L respectively. Other clearly defined regional variations include a pronounced decrease in total nitrogen levels in the West Poplar River between the International Boundary and Bredette, Montana; increases in both total nitrogen and total phosphorus in the Poplar River between the International Boundary and Scobey, Montana; and decreases in both nitrogen and phosphorus (except during the spring season) in the Poplar River between Scobey and Poplar.

Median concentrations of *boron* average about 2 mg/L in the East Poplar River at the International Boundary and about 1 mg/L elsewhere. Median concentrations of boron in the East Poplar River at the International Boundary have ranged as high as 3 mg/L during high flow periods as a result of overflows from Fife Lake. Some decrease in boron concentrations in the Poplar River at Scobey over those in the East Poplar River at the International Boundary is due to dilution by upper Poplar River water. Boron levels then decrease downstream because of dilution in the stretch of the Poplar River between Scobey and Poplar, Montana.

Except for the West Poplar River, where *dissolved oxygen* (DO) concentrations have been observed to fall to as low as 1 mg/L under ice cover, the DO content of Poplar River basin surface waters often remains greater than 4 mg/L. Autumn DO concentrations generally have the highest seasonal medians (8.0 to 11.4 mg/L). The lowest seasonal medians (2.6 to 6.3 mg/L) occur in winter and are characteristically found at the International Boundary sampling stations on the East and West Poplar rivers.

Surface waters of the Poplar River basin are generally alkaline with seasonal median pH values ranging from 7.4 to 9.7. These pH values reflect the alkaline nature of the soils in the basin. Winter median pH values are lowest (7.4 to 8.4) and spring median values are generally the same or slightly higher. Summer and autumn values are in the 8.2 to 8.9 range with one exceptionally high summer value of 9.7 recorded in the West Poplar River at the International Boundary sampling station.

Temperatures of the surface waters vary seasonally throughout the basin as a result of the variations in air temperature. The amplitudes of the observed variations are influenced by the size and depth of the water bodies. Seasonal median winter temperatures

are in the 0.0 to 0.5°C range. The corresponding summer medians are also fairly uniform, ranging from 19.0 to 22.0°C. Spring and autumn median temperatures are intermediate but tend to vary much more with location.

Turbidity The highest seasonal median turbidity values were observed during the summer season. These values were believed to be due to algal abundance.

Trace metal data for the Poplar River basin are relatively sparse compared to the information available on TDS and major ions. The data are insufficient for the examination of spatial or seasonal variations within the basin, except in the case of the East Poplar River station at the International Boundary where enough sampling has been done to provide an indication of both seasonal changes and changes due to closure of Morrison Dam. The data show that iron and manganese are generally the most abundant trace metals in the basin. Annual median concentration levels within the basin range from about 0.2 to 1.0 mg/L for total iron and from less than 0.01 up to 0.09 mg/L for total manganese. The trace-metal data for the Poplar River sampling stations indicate that the concentration of dissolved iron (but not of total iron) decreases downstream. High values for dissolved mercury were also observed in this river, but this is believed to be a consequence of sample contamination.

Pesticide data for the Poplar River basin are extremely limited. The existing data nevertheless provide information on the occurrence within the surface waters of the basin of the pesticides in common use. Of the eight pesticides for which analyses were made, the broadleaf herbicide 2, 4-D occurred in the highest concentrations, up to 0.08 micrograms per litre (μg/L). Its sources are runoff from agricultural lands and, perhaps, atmospheric fallout. Atmospheric fallout was believed to be the major source of the insecticide Gamma BHC (Lindane) and its isomer, Alpha BHC. Maximum levels of 0.001 μg/L (the detection limit) and 0.02 μg/L respectively, were found for these two pesticides. A fourth pesticide, Heptachlor, was found in two samples at the detection limit (0.003 μg/L). This insecticide probably enters the river with surface runoff. The available analyses failed to detect any other pesticides in the surface water samples.

Sampling for total and fecal *coliform bacteria* was relatively limited in scope and was inadequate to determine seasonal variations. For most of the stations in the basin the median total coliform bacteria colony count ranges from 34 to 40 per 100 mL of water and the median fecal coliform bacteria colony count ranges from 20 to 30 per 100 mL of water. The lowest median values for total and fecal coliform bacteria were 22 and 17 colonies per 100 mL, respectively, in the West Poplar River at the International Boundary. The highest median values for total and fecal coliform bacteria were 57 and 60 colonies per 100 mL, respectively, at the Poplar River station near Poplar, Montana. This station, in common with the station near Scobey, Montana also had a relatively high ratio of fecal to total coliform bacteria.

2.4.4 Water Quality in Fife Lake

Water quality data were collected in Fife Lake between 1975 and 1977. These data are not comparable with those collected at sampling sites along the three tributaries of the Poplar River because of the lack of bicarbonate data in the Fife Lake analyses. Bicarbonate was the predominant anion in the river and reservoir water analyses. Ion balances for the Fife Lake monthly data indicated there is a significant unreported anion, and this might well be the bicarbonate ion. If so, it could be present in large enough quantities to be the dominant anion in the Fife Lake waters, as it is in other surface waters of the basin.

Mean monthly TDS values for the Fife Lake waters range from 1500 to 2500 mg/L, well above the recorded TDS ranges for the river and reservoir waters. Thus, Fife Lake overflows can make significant differences to downstream water chemistry. The chemical nature of the downstream waters might also be modified if the relative composition of the major ions in Fife Lake differs from the ionic composition elsewhere in the Poplar River basin.

There is a relative scarcity of information on boron in Fife Lake waters. This element was apparently not analyzed on a regular basis during the 1975-1977 Fife Lake sampling program. An environmental assessment report prepared for SPC by Saskmont Engineering (1978) indicates that in the lake-water samples collected during 1977, boron levels ranged from 3.1 to 5.7 mg/L. The same report shows that Fife Lake overflow into Girard Creek and then into the East Poplar River, in 1975, clearly influenced boron levels in the East Poplar River at the International Boundary, where they ranged from 2.0 to 3.1 mg/L. In contrast, samples taken from the East Poplar River above the confluence with Girard Creek had boron concentrations ranging from 0.9 to 1.8 mg/L during the same sampling period.

2.5 Baseline Ground Water Quality Conditions

The natural ground waters of the Poplar River basin are generally of marginal quality and commonly exceed recommended or mandatory limits of state, provincial or federal governments for one or more chemical constituents. Although appreciable variation has been noted in chemical characteristics for some of the geological formations, it is nevertheless convenient to discuss ground water quality in the basin in terms of quality characteristics for the formations.

The *Frenchman Formation* is the deepest formation believed to play a significant role in ground water circulation within the Poplar River basin. The water is alkaline and TDS has been observed to be in the 900-1500 mg/L range. The water is generally of the sodium-bicarbonate type and it has a distinctive brown color due to unidentified organic material. Boron commonly exceeds 2 mg/L and the SAR value exceeds 25.

The Ravenscrag Formation overlies the Frenchman Formation and contains the Hart Coal Seam. Water in the *Ravenscrag Formation below the Hart Coal Seam* ranges in type from a soft sodium bicarbonate water similar to that in the Frenchman Formation through to a hard,

calcium-magnesium sulfate-bicarbonate water similar to the water in the Hart Coal Seam. The softer waters are found in the areas where the ground water returns to the surface and where the aquifer is deeply buried; the harder waters are found in the areas of infiltration and where the aquifer lies close to the surface in these areas. The water is alkaline, and measured TDS concentration has generally ranged from 935 to 1169 mg/L. One anomalously high TDS value (2732 mg/L) has also been recorded. Boron concentrations are also high for this formation, ranging from 1.7 to 2.5 mg/L.

Ground water in the *Hart Coal Seam* is generally high in TDS with concentrations usually above 1000 mg/L and ranging up to 2000 mg/L. It is very similar chemically to ground waters taken from the Ravenscrag Formation immediately above and below the Hart Coal Seam. Measured boron concentrations range from 1.5 to 2.6 mg/L. Iron and manganese concentrations are generally in the range of 1.0 to 2.0 mg/L; a few iron concentrations were less than 1.0 mg/L and a few ranged to about 10 mg/L. Manganese concentrations ranged from 0.08 to 0.45 mg/L. The Hart Coal Seam water is of particular interest because of its removal for dewatering purposes and its diversion to Girard Creek and subsequent flow into Cookson Reservoir as part of the SPC operation.

Ground water in the *Ravenscrag Formation above the Hart Coal Seam* is generally high in TDS with values commonly ranging from more than 1000 mg/L to 2500 mg/L. The observed concentrations exceeded 2500 mg/L in two cases but there were also a number of values below 1000 mg/L. This extreme variability is believed to reflect the positions of the sampling points in the ground water flow system. The water from this layer of the Ravenscrag Formation is generally a hard calcium-magnesium sulfate-bicarbonate type water. However, where the ground water in the upper Ravenscrag is moving upward from the underlying layers to discharge in perennial streams, the water is soft, and sodium and bicarbonate are the dominant dissolved constituents. Boron concentrations are generally lower than in the underlying strata and rarely exceed 2 mg/L. Iron and manganese concentrations, like the TDS concentrations, are extremely variable. A significant number of measured iron concentrations were in excess of 2 mg/L and a few exceeded 4 mg/L. Some of these high iron values may, however, be indicative of corroded well casings. Most of the observed manganese concentrations exceed 0.08 mg/L and a number range well above 1 mg/L.

Ground water in the *surficial deposits* may have low TDS and very low boron concentrations. However, where underlying formations drain upward through these deposits toward discharge in stream valleys, the water will probably have high concentrations of TDS and boron. Waters in these deposits, like those in the upper Ravenscrag Formation, are of highly variable quality.

Although it has been convenient to discuss ground water quality in terms of its variation from formation to formation, it is extremely difficult to establish with any degree of

certainty which formations are the prime sources of ground water discharging into Poplar River basin surface waters. It is reasonably certain, however, that most of the natural ground waters discharging into the major rivers and streams have travelled far enough and long enough to ensure their evolution into a high-TDS sodium bicarbonate type water.

3. WATER USES AND WATER REQUIREMENTS

3.1 Agricultural and Municipal Water Use

3.1.1 Present Usage (to the year 1975)

The principal uses of Poplar River waters have historically been related to agriculture (see Appendix D). Numerous earthen dams have been constructed over the past half century to collect spring runoff from tributary streams. The reservoirs are used primarily for watering livestock, but increased evaporation from them represents a significant loss of water and must therefore be considered a consumptive use.

Spring water spreading and full service irrigation (sprinkler and flooding irrigation) systems have also been used extensively over the period of record (1931 through the present) increasing particularly in that portion of the basin between the International Boundary and the Fort Peck Indian Reservation boundary.

The year 1931 is one of the earliest years for which discharge and water use records are available. Total water use in the basin in 1931 was approximately 125 dam^3 (100 ac-ft). By 1950, total water use in the basin had increased to about 4200 dam^3 (3,400 ac-ft). This was due principally to evaporation from the agricultural reservoirs in the basin and, to a lesser degree, to an increase in spring water spreading. Water consumption in Saskatchewan in 1950 had increased fortyfold since 1931. Uses in Montana, however, accounted for roughly 90 per cent of the estimated total water consumption in the basin in 1950.

By 1970, total full service irrigation and spring water spreading, particularly in Montana, had expanded to an estimated 11 900 dam^3 (9,650 ac-ft). All but 345 dam^3 (280 ac-ft) of that total is attributed to agricultural uses. Some 84 percent of the water use in the basin was in Montana.

Clearly, there has been an upward trend in consumptive water uses in the Poplar River basin, principally for agricultural purposes. However, the highly variable water supply from one year to the next has greatly affected these agricultural water uses. When the water has been available, it has been used.

The 1975 water uses by subbasin and use category are summarized in Table 3.1. An estimated total of 13 600 dam^3 (11,025 ac-ft) of water was used in the basin in 1975, with uses in Montana exceeding uses in Saskatchewan.

Table 3.1 EXISTING WATER USES IN THE POPLAR RIVER BASIN (1975)

	MUNICIPAL	DOMESTIC	IRRIGATION						RESERVOIR EVAPORATION	Totals
			Water Spreading		Sprinkling		Flooding			
	dam³	dam³	ha	dam³	ha	dam³	ha	dam³	dam³	dam³
Saskatchewan										
West Poplar River Subbasin	0	57	NA	31	NA	0	NA	0	284	372
Poplar River Subbasin	0	168	NA	0	NA	*	NA	64	0	232
East Poplar River Subbasin	44	464	NA	169	NA	*	NA	105	481	1263
Column Subtotals	44	689		200		*		169	765	1867
Montana										
Exclusive of Reservation										
West Poplar River Subbasin	0	470	165	408	110	777	15	111	-	1766
Poplar River Subbasin (Middle Fork)	0	150	35	90	80	567	125	952	-	1759
Poplar River Subbasin	432	412	150	377	100	679	330	2525	-	4425
East Poplar River Subbasin	0	129	425	1051	0	0	30	181	-	1361
Column Subtotals	432	1161	775	1926	290	2023	500	3769	-	9311
Fort Peck Indian Reservation										
West Poplar River Subbasin	0	109	20	48	0	0	0	0	-	157
Poplar River Subbasin	0	989	130	321	96	274	210	640	-	2224
Column Subtotals	0	1098	150	369	96	274	210	640	-	2381
TOTALS	476	2948		2495		2297		4578	765	13559

$dam^3 \times 0.8$ = acre-feet ; ha x 2.5 = acres

* Limited sprinkling irrigation is known to be practised in Saskatchewan; however a distinction between flooding and sprinkling irrigation was not made in the information provided. It is presumed the 'use' figures provided for flooding irrigation include all existing full service irrigation.

NA = not available.

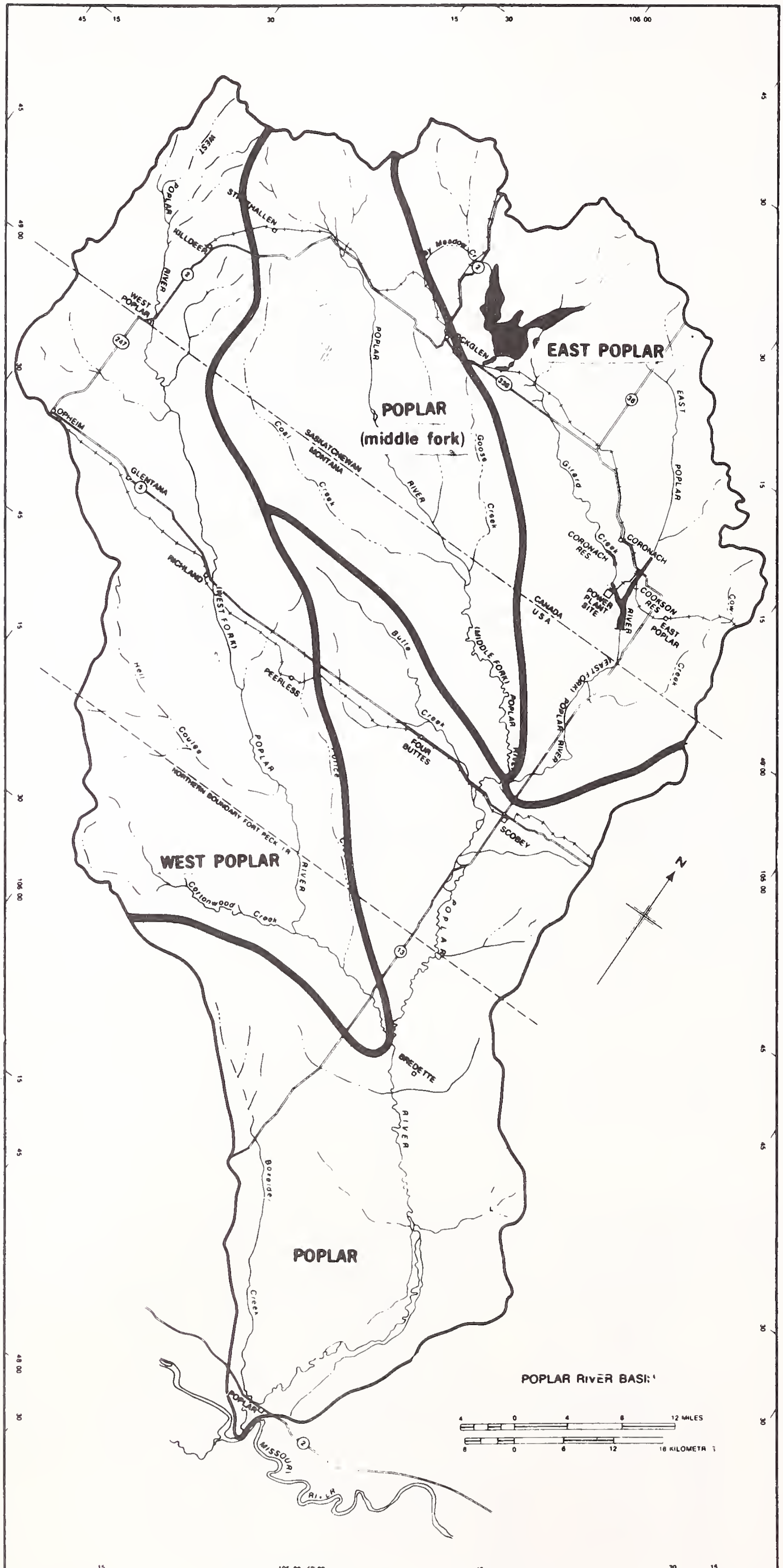

Figure 3.1 Subbasins in the Poplar River Basin.

Municipal water use in the basin is limited to the village of Coronach, Saskatchewan, and the city of Scobey, Montana. Both municipalities utilize ground water, although the alluvium which supplies the wells is recharged by surface waters. The municipal water use totals about 480 dam^3 (390 ac-ft) per year.

Domestic uses reported in Table 3.1 include evaporation losses from the numerous reservoirs in the basin as well as the amounts used by livestock. Rural household and garden irrigation uses, normally considered domestic uses, are relatively insignificant in the basin.

Irrigation is by far the largest water use in the basin, accounting for seventy percent of the total (Table 3.1). The principal crops irrigated by full service irrigation are alfalfa and grass hays. Wheat and barley are also irrigated by full service irrigation, but on a smaller scale.

3.1.2 Reasonably Foreseeable Uses

3.1.2.1 Saskatchewan

Almost all the reasonably foreseeable increase in water use expected to occur in Saskatchewan is directly or indirectly related to the SPC power plant complex and is not discussed in this section.

3.1.2.2 Montana (Exclusive of the Fort Peck Indian Reservation)

Municipal Uses. Scobey, like numerous small cities in Montana with a predominantly agricultural economic base, has experienced a population decline over the past 15 years. In the absence of industrial development near Scobey, a continued decline of slightly less than one percent per year to the year 2000 is projected. Scobey residents, however, used about 230 litres per day (60 US gal) of water per person more in 1975 than in 1970, offsetting the projected population decline in terms of total water use. Therefore, a population of 1300 in the year 2000 is expected to require approximately the same amount of water as the present population, or roughly 430 dam^3 (350 ac-ft).

Stock Watering and Reservoir Evaporation. Projections of future use with respect to stock watering and reservoir evaporation are based on a trend analysis. It is projected that about 35 000 head of cattle will be raised in the area by the year 2000. Accordingly, the number of reservoirs is expected to increase sufficiently to satisfy stock watering needs for the projected increase. It is assumed that, due to their location, aging, and other factors, the reservoirs now in existence will not be capable of satisfying the future water requirement. An increase of only 520 dam^3 (420 ac-ft) per year is the projected need for both stock watering and evaporation when compared to 1975.

Irrigation. While large areas of land suitable for irrigation remain in the Montana portion of the Poplar River basin, it is apparent that water availability and water quality will limit irrigation unless sufficient ground water sources of suitable quality can be found. Water used for irrigation, including both water spreading and full service irrigation, increased sharply in the early 1960s for alfalfa and limited small grain acreage and has continued to increase steadily. It is reasonable to assume that until water quantity and quality limitations are reached, irrigation use will continue to increase at a rate that follows the trends of the past 15 years.

Table 3.2 provides projected statistics on irrigated areas and water used for irrigation in Montana, excluding the Fort Peck Indian Reservation. Based on analysis of the number of hectares irrigated by water spreading from 1960 through 1975 and by full service irrigation from 1961 through 1975, total area-wide projections were made for the years 1985 and 2000. Land classification maps were used to determine the total projected hectares in each subbasin. It was assumed that 75 percent of the future full service irrigation would use sprinklers. The projections for future irrigation are plausible only if a sufficient water supply will be available.

It is reasonable to assume that the projected requirement of 3951 dam^3 (3200 ac-ft) for water spreading in the year 2000 could be satisfied by available water supply.

The proposed apportionment of Poplar River basin water (see Chapter 6) should enable at least three applications for full service irrigation in most growing seasons. The average number of applications available for gravity and pumping irrigation systems from 1931 through 1974 was 2.4 per year. Obviously, occasional water supply shortages have existed under current pre-apportionment irrigation use.

Because of the highly variable supply of water in the basin, it is difficult to determine at what point the projected levels of irrigation would become competitive with existing uses. Present water shortages, coupled with potential development in Montana, clearly indicate that the amount of water available to Montana in most years may not fully satisfy the projected full service irrigation demands. These constraints indicate that a water shortage may limit projected uses. Water shortages in fact occur at the present time in parts of the Poplar River basin in Montana during low-flow periods. Irrigation water is then drawn from pools and alluvial deposits in the Poplar River valley.

3.1.2.3 Montana (Fort Peck Indian Reservation)

The Sioux and Assiniboine tribes of the Fort Peck Indian Reservation have plans to construct a large storage reservoir on the lower Poplar River for use in irrigating 4000 ha (10,000 acres) of presently undeveloped land by 1985, and an additional 4000 ha (10,000 acres) by the year 2000. Projections of future water use on the reservation are shown in Table 3.3. Domestic uses, and uses associated with water spreading, are not expected to change in the future.

Table 3.2 PROJECTED FUTURE IRRIGATION IN MONTANA, 1985 AND 2000 (exclusive of the Fort Peck Indian Reservation)

Subbasin	WATER SPREADING				SPRINKLING				FLOODING			
	1985		2000		1985		2000		1985		2000	
	ha	dam^3	ha	dam^3	ha	dam^3	ha	dam^3	ha	dam^3	ha	dam^3
West Poplar River Subbasin	284	719	446	1135	168	1174	403	2820	57	430	124	934
Poplar River Subbasin (M.FK.)	87	221	151	384	140	981	340	2383	138	1044	190	1444
Poplar River Subbasin	263	668	428	1088	154	1078	356	2496	344	2611	398	3018
East Poplar River Subbasin	462	1171	530	1344	0	0	0	0	38	291	91	692
COLUMN TOTALS	1096	2779	1555	3951	462	3233	1099	7699	577	4376	803	6088

hectares x 2.5 = acres
dam^3 x 0.8 = acre-feet

Table 3.3 PROJECTED FUTURE WATER USES ON THE FORT PECK INDIAN RESERVATION (dam^3)*

Subbasin	DOMESTIC		IRRIGATION				RESERVOIR EVAPORATION	
			WATER SPREAD		FULL SERVICE			
	1985	2000	1985	2000	1985	2000	1985	2000
West Poplar River Subbasin	108	108	48	48	0	0	0	0
Poplar River Subbasin	990	990	321	321	34 726	68 871	6079	6079
TOTALS	1099	1099	369	369	34 726	68 871	6079	6079

(SOURCE: Morrison-Maierle, Incorporated, 1978).

* $dam^3 \times 0.8$ = acre-feet

In accordance with the Winters Doctrine of water rights, the Fort Peck Indian Tribes claim a quantity of Poplar River basin water for present and future uses. The Tribes contend that the full natural flow of the Poplar River is the measure of that right (See attachment 1, Appendix D). The water supply constraints operating on non-reservation lands in Montana (see previous section) also apply to the projected Indian irrigation; however, water storage is a part of that potential development and the assumed reservoir should provide an adequate water supply.

3.1.3 Water Quality Requirements

Water quality requirements necessary to protect present and reasonably foreseeable uses, municipal and domestic potable water supply, irrigation, stock watering and general agricultural uses are described in this section. For some parameters, it was impossible to define a single definitive requirement; consequently, a range of requirements has been developed.

3.1.3.1 Municipal and Domestic

The requirements for raw water quality for municipal and domestic water supply (Table 3.4) are intended to ensure that the water will be potable after treatment by coagulation, sedimentation, rapid sand filtration, and disinfection. While there is a wide range of water quality requirements in the literature, those shown should adequately protect current and reasonably foreseeable municipal and domestic uses.

3.1.3.2 Irrigation

The presence of undesirable constituents in irrigation water may suppress crop growth, reduce seed development, and impair the marketable quality of the agricultural product. In addition, some elements in irrigation water may accumulate in plants and be harmful to animals.

High concentrations of sodium in water can cause dispersion of the clay fraction in soil, resulting in surface crust formation that reduces seed germination and emergence. Highly saline waters tend to flocculate soils, resulting in relatively high infiltration rates, and have been known to cause physiological drought to plants. The effect of salinity (TDS) is one of the most important water quality considerations. Water quality requirements for irrigation supplies vary greatly depending on crops grown, water management techniques, and type of soils.

While many water quality parameters can influence irrigated crop production, for the type of crops grown and baseline water quality existing in the Poplar River basin, boron, TDS and the sodium adsorption ratio (SAR) are the only constituents considered to be critical to irrigation uses.

Table 3.4 WATER QUALITY REQUIREMENTS FOR MUNICIPAL AND DOMESTIC USES

Parameter	Not to Exceed mg/L
Chemical Characteristic	
Arsenic	0.05
Cadmium	0.01
Chromium	0.05
Copper	1.0
Fluoride	1.5
Iron	0.3
Lead	0.05
Manganese	0.05
Mercury	0.002
Nitrate (as N)	10
Sulphate	800
Microbiological Characteristics (Colonies/100 mL water)	
Coliform bacteria, Total	Geometric Mean 5 000
	Maximum 20 000
Coliform bacteria, fecal	Geometric Mean 1 000
	Maximum 2 000

Boron. Boron impairment to irrigated crop production is dependent upon the crop grown, amount of water applied, previous boron accumulation and soil type. Recent re-analysis by Dr. J.D. Rhoades, U.S. Department of Agriculture Salinity Laboratory, of past boron data has shown several discrepancies in previous boron criteria for crops. A re-examination by Dr. Rhoades of the work by Eaton (1944) relating to applied boron concentrations versus yield reduction is shown in Table 3.6 taken from the report of the Uses and Water Quality Objectives Committee (Appendix D).

Table 3.5 RELATIVE CROP YIELDS* VS BORON CONCENTRATION**

	Boron Concentration (mg/L)***					
Crop	Trace	1.0	5.0	10.0	15.0	20.0
Alfalfa	100	110	110	109	105	59
Barley grain	100	88	64	63	21	19
Barley hay	100	85	61	57	35	23
Oat grain	100	73	142	78	51	20
Oat hay	100	112	117	90	68	34
Sweet clover	100	163	215	165	159	170
Potato	100	135	120	101	83	30

* All yields are expressed as a percentage relative to the yield at trace concentrations.

** The boron concentrations do not assume any dilution effect due to rainfall as would occur under field conditions.

*** Concentration in "soil water" according to Dr. J.D. Rhoades.

The Water Uses and Water Quality Objectives Committee (Appendix D) had great difficulty in determining criteria for developing boron requirements for irrigation. It was apparent that the scientific literature provided little guidance.

The principal source of information on boron is a 1944 publication by F.M. Eaton, in the Journal of Agricultural Research (vol. 69, no. 6), entitled "Deficiency, Toxicity and Accumulation of Boron in Plants". The Committee consulted Dr. Rhoades because he has been recently re-evaluating Eaton's work for the purpose of updating a publication of the US Dept. of Agriculture: "Diagnosis and Improvement of Saline and Alkali Soils, US Salinity Laboratory, Agricultural Handbook 60 (1954)".

Dr. Rhoades explained his interpretation of Eaton's data, but confusion developed over the Committee's understanding of the explanation regarding effects on alfalfa. The Board, in reviewing the Committee report, found it necessary to consult directly with Dr. Rhoades. This resulted in the following understanding of his views on the subject.

Table 3.6 contains Eaton's data of dry weight of alfalfa harvestings for each of three successive cuttings of experimental plants, grown in solution with the indicated concentration of boron. It must be noted that these values do not represent irrigation water concentrations but rather are interpreted by Rhoades as "soil water" concentrations.

Table 3.6 WEIGHT OF ALFALFA VS. BORON CONCENTRATIONS IN SOIL WATER
(alfalfa weights in grams)

	boron "soil water" concentrations						
Cutting	Trace	1	5	10	15	25	mg/L
1	276	279	294	322	272	144	
2	128	133	127	113	151	88	
3	46	80	81	52	48	32	
TOTAL WTS	450	492	502	487	471	264	

The data demonstrate that, for the first two cuttings in the experiment, the yield was relatively uniform, or increased, up to 15 mg/L boron (soil water). However, for the third cutting, the yield increased at 1 and 5 mg/L, then returned at 15 mg/L to the yield level found at the trace concentration.

Although alfalfa is generally cut only twice annually in the Poplar River basin, Eaton's data suggest that boron might accumulate in the stems, roots and leaves, with possible additive effects in ensuing crop years. For this reason, Dr. Rhoades informed the Board that he would select a value of 8 mg/L as the limit for boron concentration in the "soil water", to avoid yield loss.

The determination of irrigation water values for boron appropriate for soil water values depends upon the soil leaching fraction, a measure of the degree to which excess water leaches out from the root zone in the soil. For the Poplar River basin, a leaching fraction value of 0.30 has been suggested by Dr. Rhoades and accepted by an agricultural specialist on the "Uses" Committee.

For the leaching fraction value of 0.30, Dr. Rhoades has proposed that a boron concentration of 4 mg/L in the irrigation water would produce the recommended soil water value of 8 mg/L for protection of alfalfa in the Poplar River basin. That is, for the soil types found in the Poplar River basin, and a leaching fraction of 0.30, a conversion factor of 0.5 was recommended by Rhoades to convert "soil water concentrations" to "irrigation water" concentrations.

On the further advice of Dr. Rhoades, the Board undertook to include the added leaching effects of precipitation, a factor not included in his analysis. Using effective precipitation values contained in Appendix D, the Board determined a value of approximately 5.5 mg/L for boron in the irrigation water, as the guideline for alfalfa crop protection.

The Board believes that the 5.5 mg/L for boron may be conservative, inasmuch as the carry over effects from one year to the next may have been excessively compensated for, an opinion shared by Dr. Rhoades. Furthermore, if the boron concentrations in Table 3.5 are irrigation water concentrations, an opinion held by at least one member of the Water Uses and Water Quality Objectives Committee, then a value of 11.0 mg/L rather than 5.5 mg/L would be an acceptable upper limit for boron in irrigation water for alfalfa. The Board, however, considers that it is not qualified to provide any recommendation other than that which can be inferred from Dr. Rhoades' advice. Dr. Rhoades has provided the Board with a written summary of his recommendation. The revision to Handbook 60 is expected in about one year, following peer review.

The effects on alfalfa of irrigation water with concentrations exceeding this 5.5 mg/L limit for boron are difficult to estimate without further research. The information contained in Table 3.6 would suggest that a yield decrease after three cuttings, in the first year, would be about 6 percent for boron concentrations of 7.5 mg/L in the irrigation water (15 mg/L in the soil water). However, the data are clearly inadequate to form a useful estimate.

The Board notes that future irrigation practices could change, with less water being used per application. Under those conditions, the leaching fraction could change from 0.3 to perhaps 0.1. Information available is insufficient to estimate the resultant effects of this on the boron concentration limit. The Board was informed, however, that for a leaching fraction of 0.2, the boron limit in the irrigation water would change from 5.5 to about 4.5 mg/L.

From information provided (see Appendix D and Table 3.6) the Board determined that the effects of boron in irrigation water on barley were more severe, and that a concentration of 0.5 mg/L was acceptable as the upper limit for the avoidance of barley yield reductions in accordance with Dr. Rhoades' assumptions.

Total Dissolved Solids. There is a large disparity in professional opinion and judgement regarding the level of total dissolved solids (TDS) which impairs crop production. Recommended acceptable levels range from 500 mg/L to 5000 mg/L as shown in Table 3.7.

Crop impairment due to elevated TDS levels is highly dependent on such factors as the amount of water applied, soil types, soil treatment, type of crops grown, and the SAR. Some potential effects of increased TDS concentrations in irrigation water, as defined by Dr. Rhoades, may include: (1) reduction in future crop diversification possibilities; (2) restriction in changing crop types to meet new demands; (3) increased need for leaching water and hence increased drainage requirements; (4) potential need for the addition of fertilizer because of increased leaching and removal of nutrients from the soil, assuming the future availability of adequate water for irrigation; and (5) increased salts (TDS) in surface water because of soil leaching.

Table 3.7 EFFECT OF TDS ON CROP PRODUCTION

TDS Concentration (mg/L)	Possible Effect
500	No detrimental effect noticed
500 - 1000	May have detrimental effects on sensitive crops
1000 - 2000	May have adverse effects on crops, requires careful management
2000 - 5000	Used for tolerant plants on permeable soils with careful management

As the content of salts applied in irrigation water increases, a yield decrease will result at some point. The amount and rate of yield decrease depends primarily on the leaching fraction, or the fraction of water not used by the plant but which passes through the root zone. The Board has determined that a reasonable value of the leaching fraction appropriate for present irrigation practices in the Poplar River basin is 0.30. Estimated alfalfa yield reductions for various TDS levels and leaching fractions are given in Table 3.8.

Table 3.8 PERCENTAGE YIELD REDUCTION OF ALFALFA AT THREE TDS CONCENTRATIONS FOR VARIOUS LEACHING FRACTIONS*

	Leaching Fraction			
TDS (mg/L)	0.1	0.2	0.3	0.4
670	0%	0%	0%	0%
1000	3	0	0	0
1350	10	4	1	0

* Values given do not assume any dilution effect due to rainfall as would occur under field conditions.

Because the effects of TDS levels on irrigated crops depend on a number of complex factors, the Board has not established a single comprehensive TDS requirement. This is primarily because, as irrigation requirements in the future begin to approach the volume of available water, smaller volumes would likely be used per application, thus reducing the leaching fraction. As shown in Table 3.8, this would result in increased yield reductions.

Sodium Adsorption Ratio. Sodium in irrigation water can become a problem in soil solution as a component of the total alkalinity which can increase the osmotic concentration causing injury to plants. Sodium can also cause problems in soil structure and infiltration. When the amount of adsorbed sodium exceeds 10 to 15 percent of the total cations in the exchange complex of a soil, the soil clays become dispersed and increasingly impermeable, unless a high concentration of total salts causes flocculation.

The adsorption of sodium on soil from a given irrigation water is a function of the proportion of sodium to calcium and magnesium in the water. The SAR is an estimation of the degree to which sodium will be adsorbed by soil from a given water.

For most crops, an SAR range of 8 to 18 is generally satisfactory, although this depends to some degree on the type of clay mineral, electrolyte concentration in the water, and other variables. For the crops grown in the Poplar River basin, the type of soil in the basin under irrigation, and the chemical characteristics of the basin's waters, an SAR value of 10 or less is recommended. The present SAR values of the basin's waters range from 2 to 16.

3.1.3.3 Stock Watering

Domestic animals represent an important segment of agriculture in the Poplar River basin. High concentrations of nutrients and toxic substances in water can adversely affect the animals. All the mineral elements essential as dietary nutrients occur in natural water. However, if they occur in excess quantities, physiological damage to animals can occur. In the Poplar River basin only sulfate and TDS are present in sufficient quantities to justify the establishment of an upper limit concentration for stock watering. Sulfate should not exceed 1000 mg/L and TDS should not exceed 3000 mg/L.

3.1.4 Effects of Present Water Use on Water Quality

Evaluation of the impact on water quality by present water usage required a thorough knowledge of the Poplar River hydrologic system. This was obtained through use of existing water quality data and the application of analytical models. These procedures were used to estimate predevelopment conditions so they could be compared to baseline (1975) conditions, to determine the impacts of existing water use on natural water quality.

The first step in determining predevelopment water quality conditions was to estimate natural flows at selected points in the basin. The relationship between water quality parameters and streamflow was then determined. Finally, these relationships were applied to estimated natural flows so as to approximate predevelopment water quality conditions.

The Apportionment Task Force estimated natural flow of the Poplar River and tributaries at selected points in Canada and the United States. Appendix B of the Apportionment Task Force Report describes the methods used and the results of those studies.

Two separate computer models, Karp II and Karp III (see Appendix A), were used in the Poplar River water quality studies to estimate predevelopment and baseline (1975) water quality conditions. The Karp II model estimates water quantity according to various assumed levels of development, and the Karp III model estimates concentrations of conservative parameters at selected points in the basin.

Input data for the Karp II model consisted of the estimated natural flows at all stations for 1931-1974 from Appendix B of the Apportionment Task Force Report. This included annual diversion requirements, monthly schedules of diversions for irrigation (spreader, flood, and sprinkler), municipal use and livestock, and return flows from irrigation. Outputs from the Karp II model included outflows, diversions, and surface and subsurface return flows at each station on a monthly basis. These data were necessary to operate the Karp III water quality model.

The Karp III model utilized output from the Karp II model as inputs and simulated the levels of conservative parameters (TDS, boron, hardness, electrical conductivity and sulfate), at selected locations throughout the basin. The SAR was calculated from sodium and hardness. Regression equations were used to obtain concentrations for stations at the International Boundary and for natural additions of flows between stations.

Small additions of flow were assigned chemical concentrations that were estimated to be values for natural ground water for each station. Sub-surface irrigation return flows were also assigned these ground water concentrations. Chemical concentrations at downstream stations were determined by a mass balance analysis for both water and salts.

The Surface Water Quality Committee examined approximately 35 scenarios to satisfy its terms of reference and the needs of other Board committees in analyzing the impact of development on various characteristics of the basin (Appendix A). Scenarios were developed for four purposes: 1) to validate the models; 2)to study water quality under a variety of growth and development situations; 3) to analyze the impact of mitigation measures; and 4) to evaluate the sensitivity of the model to assumptions necessary for cases where there were insufficient data.

The first group of these scenarios includes those which were designed to show changes in water quality with increased development up to the present time. Thus, the calculations estimate water quality before any development in the basin and at the 1975 level of development in Canada and the United States.

The change in streamflow from the natural condition to the 1975 level of development for seven selected stations is shown in Table 3.9 (see Figure 3.2 for station locations). The table confirms that most of the existing development has occurred in the United States portion of the basin (see Section 3.1). Depletions due to existing development are relatively significant at stations 8, 11, and 12 (stations at the lower end of the basin) while depletions at the International Boundary are negligible.

3.1.4.1 Effects of Present Water Use on Streamflow, TDS, Boron and SAR for Various Stream Reaches in the Basin

The effects of present water use on streamflow, TDS, boron and SAR in four reaches of the Poplar River basin are described below (see Figure 3.2 for locations).

Table 3.9 COMPUTED PREDEVELOPMENT AND HISTORIC BASELINE (1975) STREAMFLOW SCENARIOS FOR SELECTED SITES IN THE POPLAR RIVER BASIN

			Streamflow (cubic decameters)*											
STATION**	SCENARIO	STATISTIC***	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
West Poplar River at International Boundary (9)	Predevelopment	mean	.00	0	1.34	3.05	.15	.20	.05	.03	.02	.02	.02	.00
	Historic Baseline (1975)	mean	.00	0	1.10	2.91	.15	.20	.05	.03	.02	.02	.02	.00
		percent change	0	0	18	5	0	0	0	0	0	0	0	0
West Poplar River near Bredette (11)	Predevelopment	mean	.05	.07	10.29	15.07	2.07	1.81	.52	.30	.20	.25	.18	.10
	Historic Baseline (1975)	mean	.06	.07	9.18	14.63	1.96	1.64	.21	.06	.12	.27	.19	.11
		percent change	(20)	0	11	3	5	9	60	80	40	(8)	(6)	(10)
Poplar River at International Boundary (4)	Predevelopment	mean	.01	.05	5.45	6.79	1.39	1.30	.54	.15	.10	.19	.14	.06
	Historic baseline (1975)	mean	.01	.05	5.25	6.76	1.39	1.30	.54	.15	.10	.19	.14	.06
		percent change	0	0	4	1	0	0	0	0	0	0	0	0
Poplar River near Scobey (7)	Predevelopment	mean	.01	.03	8.67	12.12	2.59	2.14	.88	.24	.18	.30	.17	.05
	Historic Baseline (1975)	mean	.03	.04	8.29	12.04	2.35	1.81	.53	.06	.03	.35	.19	.07
		percent change	(200)	(33)	4	1	9	15	40	75	83	(17)	(12)	(40)
East Poplar River at International Boundary (1)	Predevelopment	mean	.06	.12	4.99	6.78	1.22	.67	.46	.32	.36	.38	.27	.16
	Historic Baseline (1975)	mean	.06	.12	4.04	6.52	1.21	.66	.45	.32	.36	.38	.27	.16
		percent change	0	0	19	4	1	1	2	0	0	0	0	0
East Poplar River near Scobey (3)	Predevelopment	mean	.04	.13	8.11	10.92	1.49	.95	.78	.44	.51	.55	.31	.14
	Historic Baseline (1975)	mean	.03	.12	6.34	10.38	1.43	.86	.66	.35	.45	.52	.29	.13
		percent change	25	8	22	5	4	9	15	20	12	5	6	7
Poplar River near Poplar (12)	Predevelopment	mean	.42	.74	30.90	53.81	10.05	7.35	6.94	1.80	1.59	1.83	1.74	.99
	Historic Baseline (1975)	mean	.47	.76	25.95	52.69	9.25	6.22	5.35	.72	.98	1.95	1.79	1.04
		percent change	(12)	(3)	16	2	8	15	23	60	38	(7)	(3)	(5)

* $dam^3 \times 0.8$ = ac/ft.
** Station locations shown in Figure 3.2.
*** Parentheses indicate an increase in streamflow.

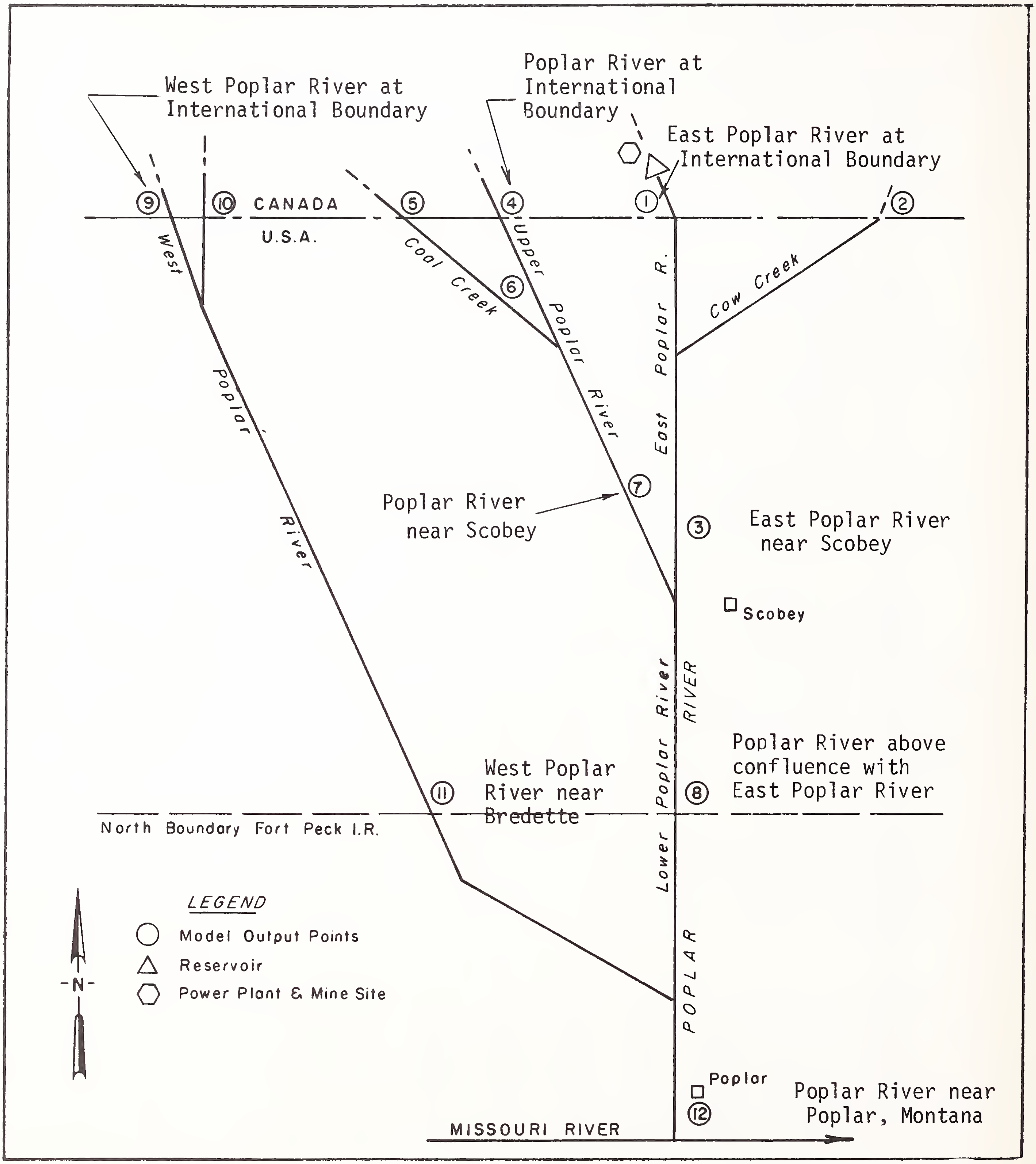

Figure 3.2 Schematic of Poplar River Basin showing stations where water quality predictions are made.

West Poplar River

Streamflow. Streamflow in the West Poplar River at the International Boundary has been only slightly changed because development on this stream in Canada has been negligible. Irrigation and the development of small stock water reservoirs in the United States, however, have caused depletions from March through September (see Table 3.9). Return flow from irrigation augments streamflow during portions of the non-irrigation season.

Total Dissolved Solids. For both scenarios, predevelopment and historical (1975 uses), predicted median monthly TDS values are essentially the same at all stations, indicating that present uses have had little effect on TDS concentrations in the West Poplar River (see Table 3.10).

Boron. Forecasts of boron concentrations are essentially the same for both scenarios (see Table 3.11).

Sodium Adsorption Ratios*. Sodium adsorption ratio predictions for both scenarios are essentially the same, indicating little impact from existing uses of the West Poplar River (see Table 3.12).

Upper Poplar River (above confluence with East Poplar River).

Streamflow. At the boundary station, predicted streamflows are almost identical for both scenarios. However, at the station above the confluence with the East Poplar River, the flows are significantly reduced by present water use in July, August and September (see Table 3.9). Delayed return irrigation flows in the United States augment non-irrigation season flows.

Total Dissolved Solids. The 1975 level of development resulted in lower flows during the July, August and September period than occurred in the predevelopment scenario. It is indicated in Table 3.10 that present water use has reduced TDS concentrations. This is misleading because the model did not predict TDS concentrations when streamflow was less than .0142 m^3/s (0.5 cfs). Streamflow was often below this limit in some months included in the analysis and TDS concentration predictions were not made for these months even though it is likely they would be quite high. Therefore, it is estimated that present water use has had a substantial impact on TDS concentrations during July, August and September at this location. If only the model output for the years which have results for the historic scenario were selected from the predevelopment scenario (nine years for July, three years for August, and three years for September), a similar conclusion can be made. The mean TDS concentrations of these selected years for the predevelopment scenario are

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* It was not possible to determine the SAR accurately using the water quality model. However, the estimated SAR values are shown and discussed because they indicate the relative changes expected.

Table 3.10 COMPUTED PREDEVELOPMENT AND HISTORIC BASELINE (1975) TDS SCENARIOS FOR SELECTED SITES IN THE POPLAR RIVER BASIN

			Concentration of Total Dissolved Solids (mg/L)											
STATION***	SCENARIO	STATISTIC*	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
West Poplar River at International Boundary (9)	Predevelopment	mean	**	**	430	420	640	610	680	670	670	750	720	**
	Historic Baseline (1975)	mean			430	490	640	600	680	670	670	750	720	
		percent change			0	17	0	(2)	0	0	0	0	0	
West Poplar River near Bredette (11)	Predevelopment	mean	800	780	440	420	610	650	720	820	800	820	820	810
	Historic Baseline (1975)	mean	800	790	440	430	610	660	730	780	800	810	820	810
		percent change	0	1	0	2	0	2	1	(5)	0	(1)	0	0
Poplar River at International Border (4)	Predevelopment	mean	760	710	530	530	590	630	670	710	720	710	740	770
	Historic Baseline (1975)	mean	760	710	590	540	590	630	670	710	720	710	740	770
		percent change	0	0	11	2	0	0	0	0	0	0	0	0
Poplar River near Scobey (7)	Predevelopment	mean	830	810	530	530	630	730	940	960	1070	900	810	1050
	Historic Baseline (1975)	mean	1070	960	550	530	640	700	630	730	820	1040	870	1170
		percent change	29	19	4	0	2	(4)	(33)	(24)	(23)	16	7	11
East Poplar River at International Boundary (1)	Predevelopment	mean	1420	1210	440	350	530	610	700	800	750	730	840	1070
	Historic Baseline (1975)	mean	1450	1230	360	470	550	620	720	820	770	740	840	1080
		percent change	2	2	(18)	34	4	2	3	3	3	1	0	1
East Poplar River near Scobey (3)	Predevelopment	mean	1270	1130	560	490	640	700	780	860	820	800	870	1070
	Historic Baseline (1975)	mean	1260	1130	540	510	650	710	780	860	830	800	880	1080
		percent change	(1)	0	(4)	4	2	1	0	0	1	0	1	1
Poplar River near Poplar (12)	Predevelopment	mean	1230	1220	480	490	670	750	840	970	1010	960	1000	1140
	Historic Baseline (1975)	mean	1230	1210	500	510	690	790	960	1230	1200	980	1010	1150
		percent change	0	(1)	4	4	3	5	14	27	19	2	1	1

* Parentheses indicate a decrease in TDS concentrations. This decrease shown during June, July, August and September for the Poplar River station 7 is misleading. The model did not predict TDS values when streamflow was less than .0142 m^3/s (0.5 cfs) even though TDS concentrations can be expected to be quite high at these low flow periods. Ignoring these presumably high concentrations results in the misleading decreases in mean concentrations.

** Concentrations not predicted in these months.

*** Station locations shown in Figure 3.2

Table 3.11 COMPUTED PREDEVELOPMENT AND HISTORIC BASELINE (1975) BORON SCENARIOS FOR SELECTED SITES IN THE POPLAR RIVER BASIN

STATION***	SCENARIO	STATISTIC*	Concentration of Boron (mg/L) Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
West Poplar River at International Boundary (9)	Predevelopment	mean	**	**	.6	.6	.8	.7	.8	.8	.8	.9	.8	**
	Historic Baseline (1975)	mean			1.0	.7	.8	.7	.8	.8	.8	.9	.8	
		percent change			67	17	0	0	0	0	0	0	0	
West Poplar River near Bredette (11)	Predevelopment	mean	.5	.5	.2	.2	.4	.5	.6	.7	.6	.7	.6	.5
	Historic Baseline (1975)	mean	.5	.5	.2	.2	.4	.5	.6	.7	.6	.7	.6	.5
		percent change	0	0	0	0	0	0	0	0	0	0	0	0
Poplar River at International Boundary (4)	Predevelopment	mean	1.1	1.0	.7	.7	.8	.9	1.0	1.0	1.0	1.0	1.1	1.1
	Historic Baseline (1975)	mean	1.1	1.0	.8	.7	.8	.9	1.0	1.0	1.0	1.0	1.1	1.1
		percent change	0	0	14	0	0	0	0	0	0	0	0	0
Poplar River near Scobey (7)	Predevelopment	mean	1.2	1.2	.7	.7	.9	1.1	1.4	1.5	1.7	1.4	1.2	1.6
	Historic Baseline (1975)	mean	1.6	1.4	.8	.7	.9	1.0	.9	1.0	1.2	1.5	1.3	1.8
		percent change	33	17	14	0	0	(9)	(36)	(33)	(29)	7	8	13
East Poplar River at International Boundary (1)	Predevelopment	mean	2.8	2.4	.7	.6	.9	1.1	1.3	1.5	1.4	1.4	1.6	2.1
	Historic Baseline (1975)	mean	2.9	2.4	.5	.8	1.0	1.1	1.3	1.6	1.4	1.4	1.6	2.1
		percent change	4	0	(29)	33	11	0	0	6	0	0	0	0
East Poplar River near Scobey (3)	Predevelopment	mean	2.5	2.2	1.0	.8	1.1	1.3	1.4	1.6	1.5	1.5	1.6	2.1
	Historic Baseline (1975)	mean	2.4	2.2	.9	.9	1.2	1.3	1.4	1.6	1.5	1.5	1.6	2.1
		percent change	(4)	0	(10)	13	9	0	0	0	0	0	0	0
Poplar River near Poplar (12)	Predevelopment	mean	1.3	1.3	.5	.6	.8	.9	1.0	1.2	1.2	1.1	1.2	1.3
	Historic Baseline (1975)	mean	1.3	1.3	.5	.6	.8	.9	.9	1.0	1.0	1.2	1.2	1.3
		percent change	0	0	0	0	0	0	(10)	(17)	(17)	9	0	0

* Parentheses indicate a decrease in Boron levels. Footnote to Table 3.10 also applies to this table.
** Concentrations not predicted for these months.
*** Station locations shown in Figure 3.2

Table 3.12 COMPUTED PREDEVELOPMENT AND HISTORIC BASELINE (1975) SAR SCENARIOS FOR SELECTED SITES IN THE POPLAR RIVER BASIN

			Sodium Adsorption Ratio											
STATION***	SCENARIO	STATISTIC*	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
West Poplar River at International Boundary (9)	Predevelopment	mean	**	**	6.9	6.9	7.9	7.8	8.1	8.0	8.1	8.4	8.3	**
	Historic Baseline (1975)	mean			8.7	7.3	7.9	7.7	8.1	8.0	8.1	8.4	8.3	
		percent change			26	6	0	(1)	0	0	0	0	0	
West Poplar River near Bredette (11)	Predevelopment	mean	9.6	9.5	9.0	8.9	9.1	9.2	9.2	9.4	9.5	9.5	9.5	9.6
	Historic Baseline (1975)	mean	9.6	9.5	9.1	9.0	9.1	9.2	9.3	9.3	9.5	9.5	9.5	9.6
		percent change	0	0	1	1	0	0	1	(1)	0	0	0	0
Poplar River at International Boundary (4)	Predevelopment	mean	5.0	4.7	3.1	3.2	3.7	4.0	4.3	4.6	4.7	4.6	4.9	5.1
	Historic Baseline (1975)	mean	5.0	4.7	3.3	3.2	3.7	4.0	4.3	4.6	4.7	4.6	4.9	5.1
		percent change	0	0	6	0	0	0	0	0	0	0	0	0
Poplar River near Scobey (7)	Predevelopment	mean	5.6	5.4	3.4	3.4	4.3	4.9	6.3	6.4	7.1	6.1	5.4	6.8
	Historic Baseline (1975)	mean	6.7	6.2	3.4	3.4	4.4	4.7	4.2	4.8	5.4	6.7	5.7	7.3
		percent change	20	15	0	0	2	(4)	(33)	(25)	(24)	10	6	7
East Poplar River at International Boundary (1)	Predevelopment	mean	5.0	4.5	1.8	1.6	2.5	2.8	3.1	3.4	3.3	3.2	3.6	4.2
	Historic Baseline (1975)	mean	5.1	4.5	1.2	1.8	2.5	2.8	3.2	3.5	3.3	3.2	3.6	4.2
		percent change	2	0	(33)	13	0	0	3	3	0	0	0	0
East Poplar River near Scobey (3)	Predevelopment	mean	4.9	4.5	3.3	3.2	3.6	3.8	4.1	4.3	4.2	4.2	4.0	4.3
	Historic Baseline (1975)	mean	5.0	4.5	3.4	3.3	3.8	3.9	4.2	4.4	4.3	4.2	4.0	4.4
		percent change	2	0	3	3	6	3	2	2	2	0	0	2
Poplar River near Poplar (12)	Predevelopment	mean	7.9	7.6	5.4	4.8	5.7	6.1	6.5	7.0	6.8	6.7	6.9	7.3
	Historic Baseline (1975)	mean	7.9	7.6	5.3	4.9	5.9	6.6	7.6	8.7	8.1	6.8	7.0	7.4
		percent change	0	0	(2)	2	4	8	17	24	19	1	1	1

* Parenthesis indicates decrease in ratio. Footnote to Table 3.10 also applies here.
** Ratio not predicted for these months.
*** Station locations shown in Figure 3.2.

610, 670 and 760 mg/L for July, August, and September respectively. These can be compared to the corresponding historic concentrations of 630,730, and 820 mg/L.

Boron and Sodium Adsorption Ratio. For boron and the sodium adsorption ratio, the conclusions drawn are the same as those for TDS, namely that present water use has had a substantial impact on the concentrations of these parameters in July, August and September.

East Poplar and Lower Poplar Rivers.

Streamflow. The limited development in Canada on the East Poplar River (pre-Cookson Reservoir) has had little effect on streamflow at the International Boundary (see Table 3.9). However, present water use in the United States portion of the Poplar River basin has resulted in significant streamflow depletion during the months of July, August and September at the mouth of the Poplar River. Present water use has, however, augmented flows during a portion of the non-irrigation season.

Total Dissolved Solids. Predictions concerning TDS concentration for both scenarios are essentially the same at the International Boundary and at the East Poplar River near Scobey. However, reduced flows during July, August and September in the historical scenario have caused higher TDS concentrations at the mouth of the Poplar River (see Table 3.10).

Boron and Sodium Adsorption Ratio. Both the predevelopment and historical scenarios yielded very similar predictions in the East Poplar and lower Poplar Rivers, indicating that present water use has only slightly affected these parameters (see Tables 3.11 and 3.12).

3.1.5 Effects of Present Water Uses on Other Uses.

As indicated in Section 3.1.4, present water use (the majority of 1975 level of development has occurred in the United States) has had an impact on water quality in the Poplar River. Even under estimated natural conditions, the water quality requirements for irrigation (see Section 3.1.3) are sometimes exceeded in these streams, and it is likely that this occurred more frequently at the 1975 levels of development resulting in impacts on downstream water uses. More important, however, are the water quantity impacts caused by present water uses. These water uses have resulted in relatively severe depletions in water quantity during the months of July, August and September in the West Poplar River near Bredette and the Poplar River near Poplar (see Table 3.9).

3.2 Biological Resources Use

3.2.1 Present Water Usage

The Board recognizes the biological resources use as being pervasive and complex. The biota includes aquatic plants and invertebrate fauna, as well as fish and stream-dependent

wildlife, such as waterfowl and ungulates (deer and antelope). The entire aquatic ecosystem must be considered. The habitat depends on particular features of water quality and stream morphometry.

The magnitude of the use of these biological resources is not large because of the limited habitat available. It is important, however, to the local communities that have traditionally utilized it. There is a limited recreational fishery, mainly for walleye, for which little information is available.

3.2.2 Reasonably Foreseeable Uses

Because of the limited habitat available,there is also little possibility of foreseeable biological use being greater than past or present use.

3.2.3 Water Quality Requirements

Water quality factors which may limit biological production are presented in Table 3.13. Information available in the literature is insufficient to enable the Board to state a desirable or optimum limit with respect to any given factor. The information in Table 3.13 is from Appendix D which contains more detailed information.

The Board notes that the effects of Cookson Reservoir are already sufficient to merit inclusion in the discussion of the present situation. For that reason, the definition of water quality requirements for aquatic biota includes reference to restoration of pre-reservoir habitat conditions.

In addition to the physical and chemical characteristics shown in Table 3.13, morphometric features such as pools and riffles that provide a variety of habitat are important physical characteristics. The alteration or loss of such habitat is a direct change in quality of the aquatic environment. Habitat quality requirements for the East Poplar River in this regard are stated as "not less than" in terms of instantaneous flow in Table 3.14. The biological consequences of the present water use situation, storage in Cookson reservoir, are shown in alternative 3 in Table 3.14.

A full discussion of the changes in hydraulic geometry of the East Poplar River channel resulting from volume and velocity conditions can be found in Appendix C.

Table 3.13 WATER QUALITY REQUIREMENTS FOR INDIGENOUS BIOTA

	Not to Exceed Limit
<u>Chemical Parameters</u> (mg/L)	
Aluminum, dissolved	0.1
Ammonia (NH_3), un-ionized	0.02
Arsenic, total	0.1
Cadmium, total	0.0012
Chromium, total	0.1
Copper, total	0.005
Iron, dissolved	0.6
Lead, total	0.03
Mercury, total	0.0002
Nitrates (N)	10% above historic seasonal concentrations
Oxygen, dissolved	
10 April - 15 May	>5.0
16 May - 9 April	>4.0
Phosphates (P)	10% above historic seasonal concentrations
pH	6.5-9.0
Sulfate	1500
Total Dissolved Solids (TDS)	2500
Zinc, total	0.03
<u>Physical Characteristics</u>	
Temperature $^{\circ}C$	
10 April - 15 May	natural ambient
any one-week period	20
maximum	30
Turbidity[1] J.T.U.	±20%

1. Turbidity shall not be caused to deviate more than ±20% of historic values based on correlations of historic streamflow vs. turbidity measurements.

Table 3.14 STREAMFLOW REQUIREMENTS FOR EAST POPLAR RIVER AT THE INTERNATIONAL BOUNDARY NECESSARY TO ACHIEVE VARIOUS BIOLOGICAL OBJECTIVES

Biological Objective	Minimum Instantaneous Flow				Annual Flow		% Mean Annual Flow to U.S.	Biological Consequences
	April (m^3/s)	May (m^3/s)	Annual (m^3/s)	Dominant Discharge[1] (m^3/s)	(dam^3)	(ac-ft)		
1. 100% restoration of habitat for game fish.	0.4	0.3	0.1	3.5 - 20 (18 d) (2 d)	13 075	10 600	92	-as was prior to 1977 i.e. no impact.
2. Partial restoration of fish habitat: the stream morphology-channel integrity component (excludes spring and annual flow requirements).	x	x	0.1	3.5 - 20 (18 d) (2 d)	11 457	9 288	81	-spawning will not occur most years. -little impact for wildlife, plants, and invertebrates, but serious for fish.
3. Partial restoration of fish habitat: the spring and annual flow requirement (excludes stream morphology and channel integrity requirements).	0.4	0.3	0.1	x	3 873	3 140	27	-severe degradation of most habitat, loss of most game fish. -impact as at present on wildlife, plants, and invertebrates.
4. Maintain minimum streamflow	0.1 m^3/s year round			x	2 541	2 060	18	-spawning will not occur in most years. -loss of most game fish.

[1]A release or spill of water from Cookson Reservoir with discharge exceeding 3.5 m^3/s (123 cfs) for 18 days and 20 m^3/s (700 cfs) for two days within that period at the International Border; this release should gradually build up to 20 m^3/s peak and then recede over a period of several days; the release should occur between March 15 and April 5.

$m^3/s \times 35.3 = cfs$

4. INTERNATIONAL BOUNDARY WATER QUALITY OBJECTIVES

Based on the water quality requirements for individual uses, discussed in the preceding chapter and in more detail in Appendix D, multiple purpose water quality objectives have been developed for the basin by the Uses and Water Quality Objectives Committee. The objectives, as proposed by the Board, are applicable at the International Boundary, and have been numerically determined in such a way as to provide protection to present and reasonably foreseeable uses downstream at the point of use. They should not be used as absolute values of water quality but with considered judgement backed by an adequate monitoring program and with an understanding of their development as delineated in Appendix D. If used objectively, they should give an adequate degree of protective assurance for water users. However, because knowledge of the necessary criteria is constantly changing, these objectives should be adjusted when necessary and they should be systematically reviewed every 5 years.

Table 4.1 contains recommended values for objectives at the International Boundary for parameters considered to be appropriate, with exceptions as explained later. Chemical substances other than those for which objectives have been developed may also affect water quality. However, such substances are believed to be present at insignificant concentrations in the Poplar River basin and their concentrations are not expected to be increased by foreseeable developments.

It was apparent that the naturally occurring concentrations of iron and manganese commonly exceed the recommended limits for drinking water. Because the treatment of municipal water to reduce the effects of these two elements is simple and inexpensive, no objectives were set.

Those items not included in Table 4.1 which are of significance to the Poplar River system are boron and TDS. As discussed in the preceding chapter and in Appendix D, the concentrations of boron and TDS are naturally high, and increasing concentrations of these substances can have deleterious effects on the production of some crops. Therefore, limits have been recommended on the basis of protection for specific uses in the Poplar River basin.

In this chapter, the Board also presents the specification of water quantity guidelines which it considers are necessary for the protection of biological habitat in the East Poplar River below the SPC development.

Table 4.1 RECOMMENDED MULTIPURPOSE WATER QUALITY OBJECTIVES FOR THE POPLAR RIVER SYSTEM AT THE INTERNATIONAL BOUNDARY

		Not to Exceed Limit
<u>Chemical Parameters (mg/L)</u>		
Aluminum (Al), dissolved		0.1
Ammonia (NH_3), free		0.02
Cadmium (Cd)		0.0012
Chromium (Cr)		0.05
Copper (Cu), dissolved		0.005
Copper (Cu)		1.0
Fluoride (F)		1.5
Lead (Pb)		0.03
Mercury (Hg), dissolved		0.0002
Mercury (Hg), whole fish		0.5
Nitrate (N)		10.0
Oxygen (O_2), dissolved		minimum 5.0 (April 10 to May 15) minimum 4.0 (remainder of year)
SAR		10.0
Sulfate (SO_4)		800
Zinc (Zn)		0.03
pH		minimum 6.5 & <0.5 above natural
<u>Physical Parameters</u>		
Temperature C°		Natural (April 10 to May 15) <30 (remainder of year)
Flow m^3/s		3.5 for 18 consecutive days; 20 for 2 consecutive days or some lesser period as feasible, depending on natural flow regime (see Section 4.3)
<u>Microbiological Parameters</u>		
Coliform, bacteria geometric mean		
-fecal	Colony Counts/100 mL	1000
-total	Colony Counts/100 mL	5000
Coliform, bacteria maximum densities		
-fecal	Colony Counts/100 mL	2000
-total	Colony Counts/100 mL	20 000

4.1 Boron

The effects of boron concentrations in water used for crop irrigation depend upon the crop grown, the amount of water applied, the previous accumulation of boron in the soil and the soil type. Table 3.5 and 3.6 and the accompanying discussion describe the effects of boron on yields of certain crop types, under conditions representative of the Poplar River basin.

Alfalfa is the principal crop irrigated in the basin. The Board has determined that alfalfa should be tolerant of boron concentrations in the irrigation water up to 5.5 mg/L (Section 3.1.3.2). Thus the production of alfalfa will not be affected by natural concentrations of boron. Protection of alfalfa crops presently irrigated along the East Poplar River between the International Boundary and the confluence with the Poplar River will require a boron objective of 6.0 mg/L at the International Boundary. If future irrigation of alfalfa occurs immediately south of the International Boundary, a boundary water quality objective of 5.5 mg/L will be required. Because of dilution effects, protection of alfalfa crops south of the confluence of the East Poplar and the Poplar rivers will require a boundary water quality objective of 13.4 mg/L boron.

The crop most sensitive to boron, grown under irrigation in the basin, is barley. Yields of irrigated barley under natural conditions are probably less than optimum, because naturally occurring boron concentrations during the irrigation season average about 2.0 mg/L. Consequently, any development which adds to the boron concentration will further reduce barley crop yields. An International Boundary water quality objective for boron necessary to protect barley irrigated in the East Poplar River basin between the International Boundary and the confluence with the Poplar River from further yield reductions is therefore the natural concentration (about 2 mg/L).

It should be noted that the boron objective proposed for the protection of crops irrigated in the East Poplar subbasin is based on the assumption of a leaching fraction of 0.3. The Board notes that future irrigation practices could result in the use of less water per application, with a resultant decrease in the leaching fraction. The results to be expected from this are not well known, although the Board has determined that, for a leaching fraction of 0.2, the boron objective at the International Boundary would need to be decreased from 6 to about 5 mg/L (see Section 3.1.3.2) for protection of alfalfa.

4.2 Total Dissolved Solids

Crop impairment due to elevated TDS concentrations is also highly dependent on such factors as the amount of water applied, soil types, soil treatment, types of crops grown, and the sodium absorption ratio (SAR). Of the above factors, only the amount of water applied is likely to affect crop yields in the Poplar River basin.

The effects of TDS on irrigated crops has been generally described in Section 3.1.3. If the TDS of the irrigation water increases, more of that water will have to be applied per acre or crop yields will decrease. If there is no shortage of water, excess water can be applied. If there is a shortage of water, crop yields per acre will decrease, or, if yields are maintained, fewer acres can be irrigated.

At the present time in the Poplar River basin, there may be sufficient water available (and perhaps used) to maintain acceptable concentrations of salts in most of the soils which are irrigated. Judging from the surface salts accumulation on some of the irrigated fields in the basin, the necessary excess water is not being applied in all cases. This may be due to soil characteristics, that is, these soils may not be porous enough to allow the necessary water to pass through. It may also be due to improper application of water.

At predicted future development levels (1985 or 2000) surplus water will probably not be available. If this occurs, TDS concentration increases would generally cause a crop yield loss. These losses can be estimated either by assuming less land will be irrigated with slightly more water or by assuming projected irrigation development levels are reached, but with a slight yield reduction. Because there are fewer uncertainties in assuming yield reductions, this approach was used.

As with the effects of boron on barley production, the Board determined that any increase in TDS concentrations, due to new developments, could result in some degree of yield reduction of irrigated alfalfa if the leaching fraction were lowered. Therefore, as with boron, the Board decided to present a tabulation of predicted effects for a range of possible increased TDS concentrations in the Poplar River system. Table 4.2 illustrates the TDS concentration to be expected at various points in the basin as related to those in the East Poplar River at the International Boundary, and the consequent alfalfa yield reductions, assuming a leaching fraction of 0.1 (see Table 3.8).

Table 4.2 PREDICTED MEAN TDS CONCENTRATION CHANGES DURING THE IRRIGATION SEASON RESULTING FROM GIVEN TDS CONCENTRATIONS IN THE EAST POPLAR RIVER AT THE INTERNATIONAL BOUNDARY (assuming leaching fraction of 0.1)

	TDS Concentrations (mg/L)			
Given TDS Concentrations in East Poplar River at International Boundary	674 (0)*	932 (2.0)	984 (2.5)	1010 (2.7)
Predicted TDS Concentrations in East Poplar near Scobey	774 (0.8)	932 (1.2)	976 (1.5)	976 (1.5)
Predicted TDS Concentrations in Poplar River near Indian Reservation Boundary	822 (0.1)	894 (0.5)	936 (0.9)	936 (0.9)

* Numbers in parentheses are percentage reductions in alfalfa yield.

The recommendations for TDS objectives at the International Boundary, based on present irrigation practices, are (Appendix D):

1) the long-term (10-year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1000 mg/L, and

2) the short-term (any 3-consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1500 mg/L.

4.3 Streamflow

As described in Section 3.2.3, the Board determined that streamflow characteristics which are important to the maintenance of the biological habitat of the East Poplar River could be affected by the SPC development. In fact, conditions resulting from the impoundment at Coronach have already resulted in habitat degradation (Appendix C).

The effective or channel-forming discharge in the East Poplar River at the International Boundary is approximately 20 m^3/s. Therefore, a discharge of this magnitude is necessary in order to maintain the existing channel characteristics and the aquatic habitat. The magnitude of streamflows during the spring thaw in the East Poplar is highly variable from year to year. A discharge of 20 m^3/s has been exceeded in slightly less than half of the years of record. On the average, however, a discharge of 20 m^3/s has occurred 0.5 percent of the time, or approximately 2 days per year. Consequently, the Board suggests that a discharge of 20 m^3/s for a 2 day period is essential to maintain the existing aquatic habitat of the East Poplar River, and that a discharge of this magnitude should occur in approximately half of the years in any ten years.

5. EFFECTS OF COOKSON RESERVOIR ON WATER QUALITY

5.1 Characteristics

To impound the required 7400 dam^3 (6000 ac-ft) from the flow of the East Poplar River, as a source of cooling water, SPC constructed Morrison Dam approximately 3.5 km (2.2 mi) north of the International Boundary. The dam formed the Y-shaped Cookson Reservoir within the valleys of the East Poplar River and Girard Creek. The location of Cookson Reservoir is shown in Figure 5.1. Morrison Dam is an earthfill embankment with a crest elevation of 757.0 m (2483 ft). In addition to a gated service spillway and emergency earthfill plug spillway, the dam has a low level riparian outlet for releasing flow on demand. At full supply level (FSL) of 753.0 m (2470 ft) the reservoir extends approximately 11 km (7 mi) up the East Poplar River and has a surface area of 7.4×10^6 m^2 (1.8×10^3 ac) and a volume of 41 166 dam^3 (33,375 ac-ft). In the lower 3 kms (2 mi) of the reservoir the maximum depth is relatively constant at 13-14 m (43-46 ft).

5.2 Present (1978) Effects on Water Quality

5.2.1 Surface Water

Because regular water quality monitoring on the East Poplar River began only in 1973, the data are indicative rather than definitive of long-term water quality conditions. Closure of Morrison Dam took place in late 1975 but FSL was not reached until spring 1979. By then the full evaporative effect on dissolved salts (TDS) concentration had not occurred, nor had the dilution effect of maximum runoff retention been realized.

Detailed data on water quality of Cookson Reservoir are to be found in Appendix A. To illustrate the effect of Cookson Reservoir on water quality in the East Poplar River, pre- and post-reservoir concentrations of selected chemical parameters at the International Boundary station are shown in Table 5.1.

Before closure of Morrison Dam, the chemical quality of the East Poplar River at the International Boundary was influenced only by streamflow. In spring, dilution by snowmelt reduced the concentration of chemical constituents in the water. In winter, streamflow came largely from ground water, with the result that chemical constituents were more concentrated than in spring. After dam closure, the increase in spring TDS concentration reflects the reduction of snowmelt dilution.

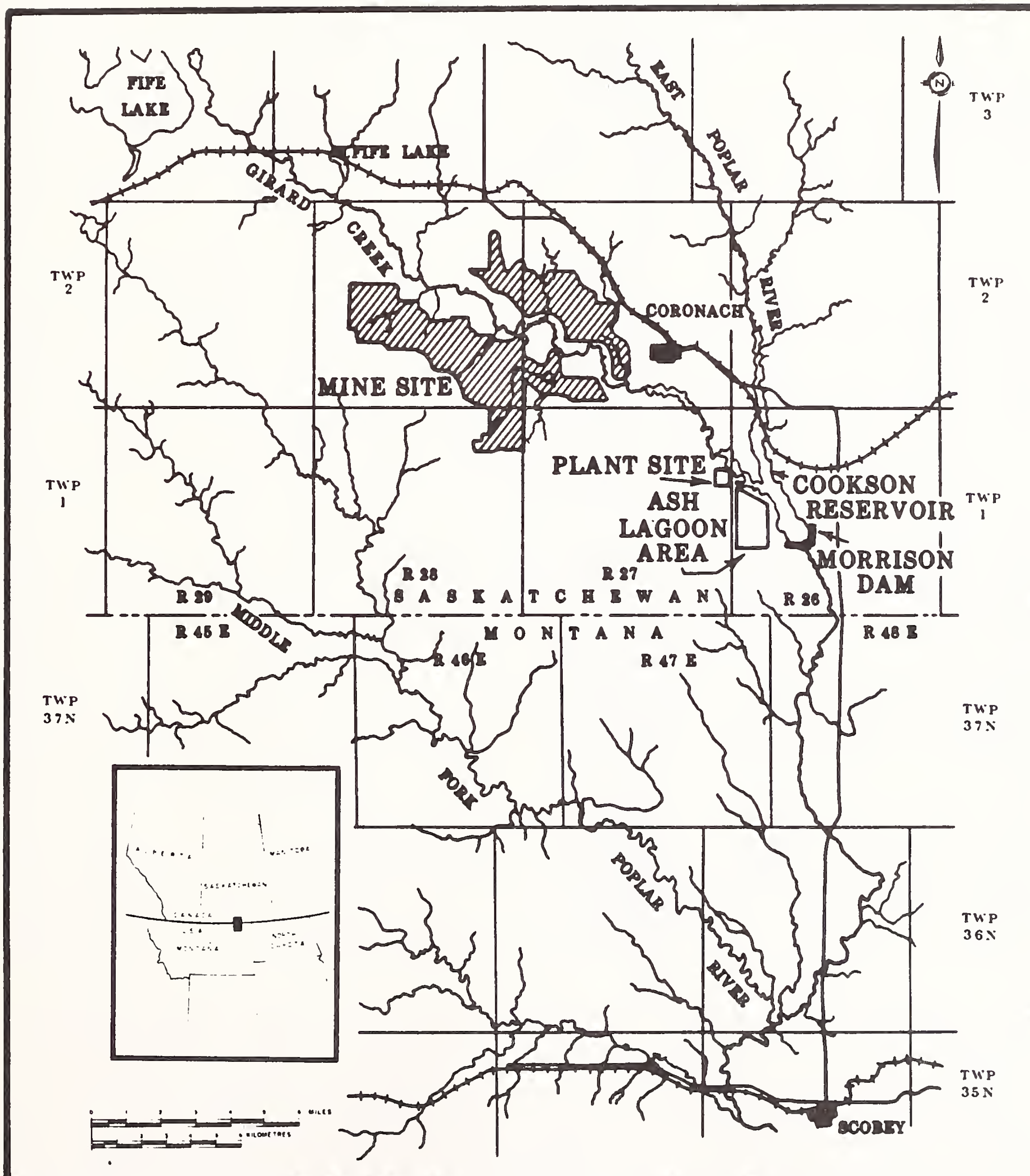

Figure 5.1 Site Location Map of the Poplar River Power Project.

Table 5.1 EFFECT OF COOKSON RESERVOIR ON WATER QUALITY IN EAST POPLAR RIVER

Parameter	BEFORE CLOSURE OF MORRISON DAM				AFTER CLOSURE OF MORRISON DAM							
	At International Boundary				At International Boundary				At Cookson Reservoir			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Median TDS mg/L	445	775	924	942	836	876	924	907	795	976	1044	1132
Median Bicarbonate mg/L	360	573	645	715	565	573	645	688	550	647	691	752
Median Sulfate mg/L	123	244	250	258	225	265	270	240	200	303	315	360
Median Sodium mg/L	69	173	204	185	188	211	214	191	191	236	270	280
Median Boron mg/L	1.05	2.75	2.04	2.30	1.26	1.97	1.95	1.80	1.88	2.00	2.04	2.15

Table 5.1 shows that dissolved minerals undergo concentration in the reservoir. The seasonal variation illustrates the natural phenomenon of concentration by evaporation which takes place in all prairie reservoirs in summer and autumn.

Cookson Reservoir has increased the spring concentration of TDS, and hence the major ions, at the International Boundary, as shown in Table 5.1. The only other apparent effect of Cookson Reservoir on the East Poplar River is a small increase in iron and possibly an increase in zinc and manganese for parts of the year (Appendix A). Increases in trace metals are probably due to ground water input to the stream. The International Boundary water quality objectives (Chapter 4) are not expected to be exceeded solely by the presence of Cookson Reservoir, except when boron concentrations reach higher levels than natural concentrations.

5.2.2 Ground Water

Although Morrison Dam was constructed with an impervious blanket on the upstream earthfill embankment, seepage will occur through the dam and the reservoir floor. As indicated in Appendix B, the direction of ground water movement is southeast, and generally toward the East Poplar River Valley near Scobey, Montana. In terms of ground water discharge, and Cookson Reservoir, the flow from valley-fill alluvial aquifers is of greatest interest. A sketch of the ground water flow system is shown in Figure 5.2.

Cookson Reservoir has caused measurable rises in ground water levels within the Hart Coal seam and overlying aquifers, notwithstanding the high pumping rate of aquifer dewatering. The rate of seepage from Cookson Reservoir was determined with a mathematical model to range from 25 to 32 L/s (approx. 1 cfs). The available field data were not sufficient for checking the accuracy of this estimate. However, the comparison of simulated and measured changes in the ground water levels for the Hart Coal aquifer shown in Figure 5.3 indicates the reliability of the modelling.

Isotope analyses indicated that most of the present seepage at the toe of Morrison Dam is ground water that is being forced to the downstream seepage area at a much higher flow rate than normal, due to the additional imposed hydraulic head resulting from the filling of the reservoir.

The principal natural source of new ground water prior to the filling of Cookson Reservoir was infiltration of snowmelt, a characteristically fresh water with a relatively low pH (5.5 to 6.5) when compared to most ground water. The ability of the natural subsurface system to alter the chemical composition of precipitation or snowmelt is obvious since the chemical composition of ground water is considerably different from that of precipitation. The effect of inflow from the reservoir on chemical quality of the ground water will, however, likely be small. The reason lies in the expected tendency of subsurface materials to react with the inflowing water in such a way as to reduce chemical changes to minor

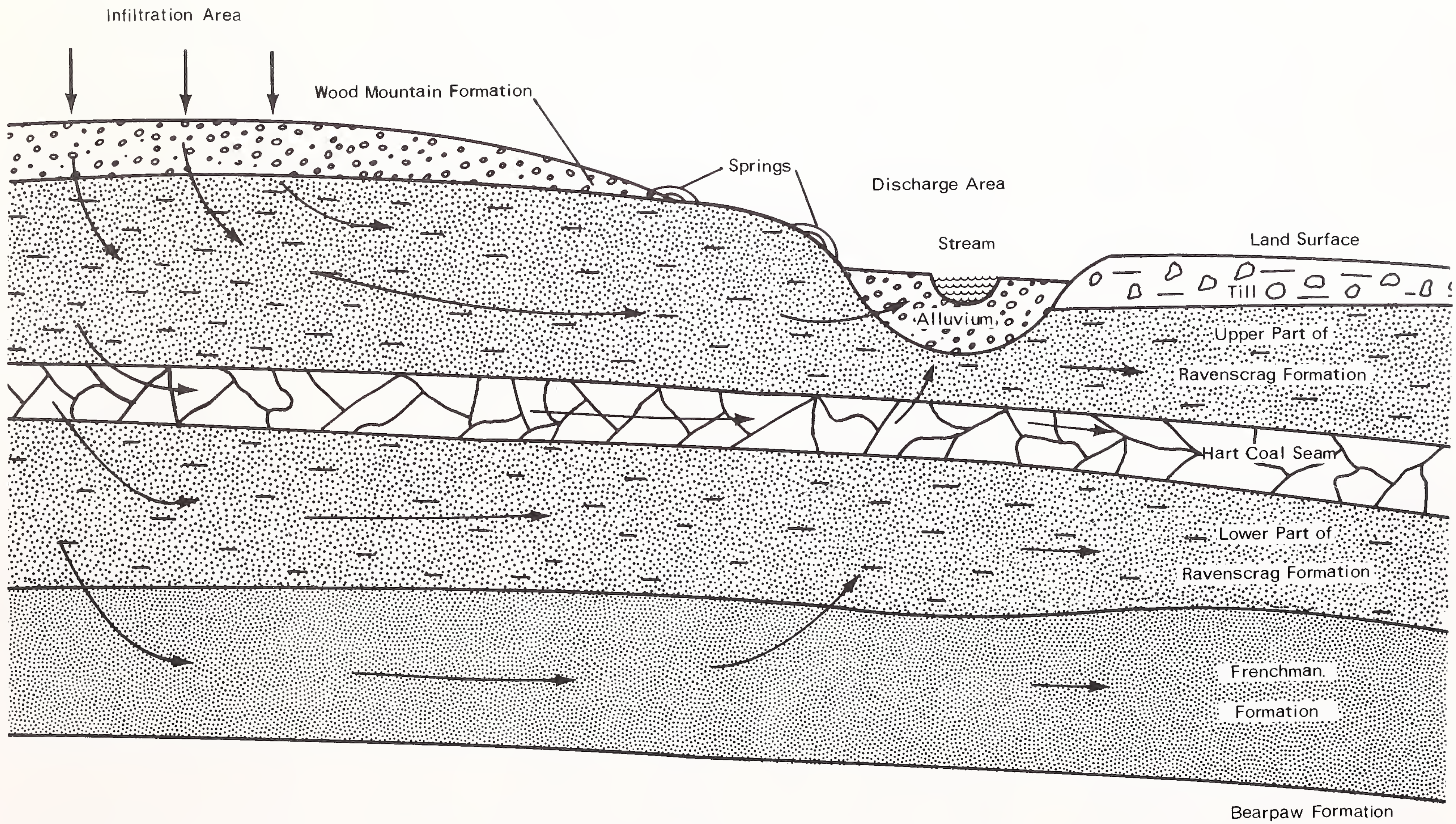

Figure 5.2 Schematic diagram showing ground water flow from infiltration areas to areas where ground water returns again to the surface.

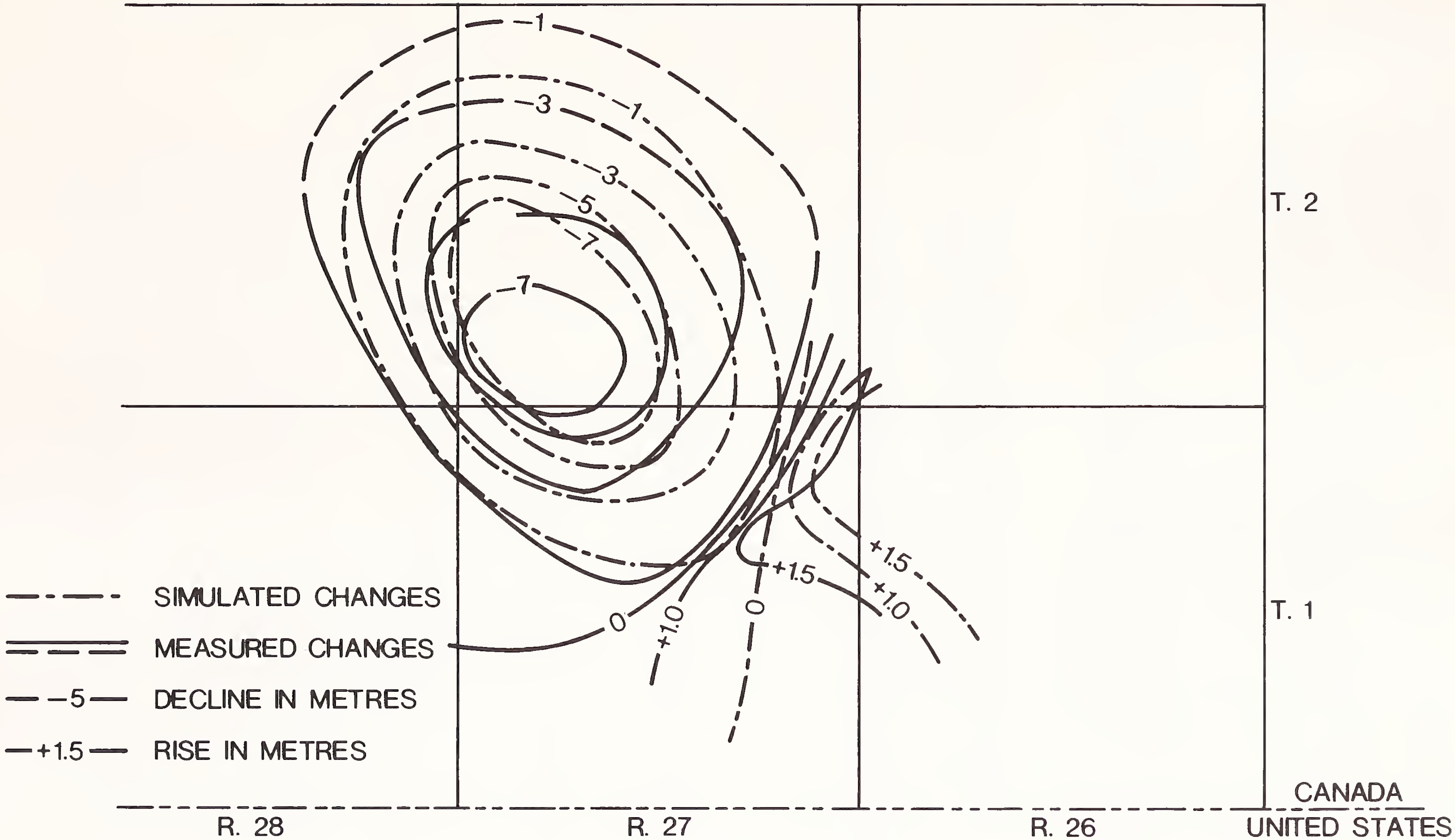

Figure 5.3 Measured and simulated changes in ground water levels in Hart Coal Aquifer spring 1976 to fall 1977.

fluctuations around theoretical solubility limits. However, constituents which are not near their solubility limits or are not readily adsorbed on soils along the flow path will tend to approach reservoir concentrations in the near-dam seepage. Nitrate and boron are in this category, although boron is known to adsorb on soils in varying degrees. In the shallow ground water flow system dominated by induced recharge from the reservoir, the sorption capacity for boron is expected to be eventually depleted and seepage flow will contain concentrations of boron similar to those found in the reservoir.

The Board concludes that over most of the study area the ground water chemical quality within the individual formations will remain similar to pre-reservoir conditions. The Board also concludes that the most noticeable effect will be in the shallow drift aquifers near Cookson Reservoir (see Appendix B).

Examination of Table 5.1 shows that ground water quality has been essentially unaffected by Cookson Reservoir. This conclusion is based on the fact that autumn and winter flow at the International Boundary is essentially derived from ground water. Comparing the water quality of the reservoir with that of streamflow for the same time period confirms that recharge water from the reservoir has not yet affected the chemical quality of the ground water.

6. EFFECTS OF FULL IMPLEMENTATION OF WATER QUANTITY APPORTIONMENT

6.1 IJC Recommendations

To undertake and report on the Poplar River investigations leading to apportionment recommendations, the International Souris-Red Rivers Engineering Board, with the approval of the Commission, appointed an International Poplar River Task Force. The report of the Task Force, submitted to the IJC in February 1976, made the following recommendations with respect to apportionment of the flows in the Poplar River basin:

The aggregate natural flow of all streams and tributaries in the Poplar River basin crossing the International Boundary shall be divided equally between Canada and the United States subject to the following conditions:

1. *The total natural flow of the West Poplar River and all its tributaries crossing the International Boundary shall be divided equally between Canada and the United States but the flow at the International Boundary in each tributary shall not be depleted by more than 60 per cent of its natural flow.*

2. *The total natural flow of all remaining streams and tributaries in the Poplar River basin crossing the International Boundary shall be divided equally between Canada and the United States. Specific conditions of this division are as follows:*

   a) *Canada shall deliver to the United States a minimum of 60 per cent of the natural flow of the Poplar River at the International Boundary, as determined below the confluence of Goose Creek and Poplar River.*

   b) *The delivery of water from Canada to the United States on the East Poplar River shall be determined on or about the first day of June of each year as follows:*

      i) *When the total natural flow of the Poplar River, as determined below the confluence of Goose Creek, during the immediately preceding March 1st to May 31st period does not exceed 4690 dam^3 (3800 ac-ft), then a continuous minimum flow of 0.028 m^3/s (1.0 cfs) shall be delivered to the United States on the East Poplar River at the International Boundary throughout the succeeding 12 month period commencing June 1st. In addition a volume of 370 dam^3 (300 ac-ft) shall be delivered to the United States upon demand at any time during the 12 month period commencing June 1st.*

ii) When the total natural flow of the Poplar River, as determined below the confluence of Goose Creek, during the immediately preceding March 1st to May 31st period is greater than 4690 dam^3 (3800 ac-ft), but does not exceed 9250 dam^3 (7550 ac-ft), then a continuous minimum flow of 0.057 m^3/s (2.0 cfs) shall be delivered to the United States on the East Poplar River at the International Boundary during the succeeding period June 1st through August 31st. A minimum delivery of 0.028 m^3/s (1.0 cfs) shall then be maintained from September 1st through to May 31st of the following year. In addition, a volume of 617 dam^3 (500 ac-ft) shall be delivered to the United States upon demand at any time during the 12 month period commencing June 1st.

iii) When the total natural flow of the Poplar River, as determined below the confluence of Goose Creek, during the immediately preceding March 1st to May 31st period is greater than 9250 dam^3 (7500 ac-ft), but does not exceed 14 800 dam^3 (12,000 ac-ft), then a continuous minimum flow of 0.085 m^3/s (3.0 cfs) shall be delivered to the United States on the East Poplar River at the International Boundary during the succeeding period June 1st through August 31st. A minimum delivery of 0.057 m^3/s (2.0 cfs) shall then be maintained from September 1st through to May 31st of the following year. In addition, a volume of 617 dam^3 (500 ac-ft) shall be delivered to the United States upon demand at any time during the 12 month period commencing June 1st.

iv) When the total natural flow of the Poplar River, as determined below the confluence of Goose Creek, during the immediately preceding March 1st to May 31st period exceeds 14 800 dam^3 (12,000 ac-ft) then a continuous minimum flow of 0.085 m^3/s (3.0 cfs) shall be delivered to the United States on the East Poplar River at the International Boundary during the succeeding period June 1st through August 31st. A minimum delivery of 0.057 m^3/s (2.0 cfs) shall then be maintained from September 1st through to May 31st of the following year. In addition, a volume of 1230 dam^3 (1000 ac-ft) shall be delivered to the United States upon demand at any time during the 12 month period commencing June 1st.

c) The natural flow at the International Boundary in each of the remaining individual tributaries shall not be depleted by more than 60 per cent of its natural flow.

3. The natural flow and division periods for apportionment purposes shall be determined, unless otherwise specified, for periods of time commensurate with the uses and requirements of both countries.

6.2 Effects on Water Quality

Water quality effects of apportionment are inseparable from the effects of the consumptive uses to which water will be put by the upstream jurisdiction. In the case of the Poplar River system, the Board cannot, therefore, evaluate the water quality effects of apportionment alone, separate from the combined effects of apportionment and the developments in Canada which will utilize the water (Cookson Reservoir and the SPC power plant).

The Board has, however, compared the effects resulting from: 1) the operation of the two unit SPC power project under circumstances where Canada would only use waters necessary for that and other foreseeable uses; with 2) the effects resulting from the two unit operation, under the full provisions of the recommended apportionment. For case 2) above, the Board has assumed a consumptive loss from hypothetical reservoirs in Canada on the Poplar River. In that hypothetical scenario, the Board assumed no deleterious water quality effects emanating from the fictitious impoundments.

The Water Uses and Water Quality Objectives Committee (Appendix D) reviewed the effect of full implementation of water quantity apportionment on water quality in relation to proposed water quality objectives. Only those water quality parameters likely to be affected by present and future uses, that is, TDS, boron, sulfate and sodium adsorption ratio, were considered.

6.2.1 Total Dissolved Solids (TDS)

It is concluded that the effect of full implementation of water quantity apportionment on TDS concentrations in the waters of the Poplar and West Poplar rivers at the International Boundary will be minimal. For example, the flow-weighted mean values over the irrigation period (May 1st to September 30th) were only increased for the Poplar River by 6 mg/L and for the West Poplar River by 76 mg/L.

Table 6.1 shows that the two-unit power plant on the East Poplar River could increase TDS by as much as 25 percent at the International Boundary during the irrigation season. However, there is essentially no additional increase in TDS at full apportionment.

6.2.2 Boron

The effect of full implementation of water quantity apportionment on boron concentrations in the waters of the Poplar and West Poplar rivers is predicted to be insignificant.

Although Table 6.1 illustrates a significant increase in boron concentrations in the East Poplar River from the effects of the proposed two-unit power plant, which will be discussed in a later section, implementation of full apportionment will have little added effect on boron concentrations.

Table 6.1 MEDIAN TDS AND BORON CONCENTRATIONS IN EAST POPLAR RIVER AT INTERNATIONAL BOUNDARY DURING THE IRRIGATION SEASON (mg/L)

	May		June		July		August		September	
Scenario	TDS	Boron	TDS	Boron	TDS	Boron	TDS	Boron	TDS	Boron
Reservoir No Power Plant	830	1.6	810	1.5	790	1.5	800	1.5	840	1.6
Two Unit Power Plant	960	6.8	980	7.5	990	8.1	1020	8.7	1050	8.2
Two Units with full apportionment	970	6.8	1010	7.3	1010	8.1	1050	8.6	1050	8.3

6.2.3 Sulfate

The effect of water quantity apportionment on sulfate concentrations in the waters of the Poplar and West Poplar rivers is predicted to be minimal. It is concluded that the sulfate concentrations would not be affected by full implementation of water quantity apportionment of the East Poplar River.

6.2.4 Sodium Adsorption Ratio (SAR)

The effect of water quantity apportionment on SAR values in the waters of the Poplar and West Poplar rivers is predicted to be minimal.

Apportionment will not adversely affect SAR values on the East Poplar River according to predictions developed by the Uses and Water Quality Objectives Committee.

6.3 Effects on Present and Future Uses

6.3.1 Irrigation and Public Water Supply

It has been shown in Section 6.2 that the water quality effects of full apportionment, compared to effects from consumption necessary only for present and foreseeable developments in Canada are expected to be of little significance. Consequently, the Board concludes that the implementation of full apportionment will have no significant added effects on downstream uses.

6.3.2 Biological Resources

It was concluded (Appendix C) that the proposed apportionment of the waters of the Poplar River basin, primarily through the regulation of Cookson Reservoir, would lead to substantial changes in the flow and channel characteristics of the East Poplar and Poplar rivers. Specifically, the Committee foresees the following ranges in percentage reduction of bankfull hydraulic characteristics shown in Table 6.2.

Table 6.2 RANGE OF REDUCTION IN BANKFULL CHARACTERISTICS UNDER PROPOSED APPORTIONMENT
(values are given in percent)

	Width	Depth	Velocity
East Poplar River	53-68	42-56	15-21
Poplar River	17-40	13-31	4-10

From these hydraulic changes the Committee predicts habitat changes with the result that the following impacts on the biological resources of the Poplar River basin in Montana will occur:

1. up to a 50 percent increase in growth of rooted aquatic plants (macrophytes) in the East Poplar River;

2. up to a 25 percent decrease in the quantity of streamflow dependent algae in the East Poplar River;

3. up to a 75 percent decrease in the walleye population in the lower East Poplar River due to loss of habitat; and,

4. up to a 50 percent reduction in annual duck production in the East Poplar River due to habitat alteration, primarily resulting from encroachment by rooted aquatic plants. The reduction is estimated to be 70-80 pairs of breeding ducks.

In order to restore habitat to pre-reservoir conditions and maintain channel integrity, specific peak flows will be required, preferably in the period March 15 to April 5. These are defined in Section 4.3.

7. EFFECTS OF SASKATCHEWAN POWER CORPORATION PROJECT ON WATER QUALITY

7.1 Characteristics

The major features of the Poplar River power development are a lignite open pit mine, a thermal power plant, and a cooling reservoir (Cookson Reservoir) formed by construction of Morrison Dam on the East Poplar River. Associated with these major features are facilities for storing and transporting lignite from the mine to the power plant and an increased permanent and temporary population in the area, particularly in the village of Coronach. Each of these development features is given in Figure 7.1. Cookson Reservoir was described in Chapter 5.

The present scheduling for the Poplar River project indicates commissioning of the first power unit on March 1, 1980. This means that some pre-commissioning operation will occur during the winter of 1979-80, requiring that the ash disposal system for the plant be constructed and operational by the fall of 1979. Construction of the powerhouse for the first unit is now partially completed and will be finalized during the summer of 1979. The second unit is expected to come on line in 1982. The initial cut in the coal mining area has been started and lignite removal will commence during the summer of 1979.

7.1.1 Mining

There are an estimated 400 million tonnes (440 million short tons) of economically recoverable lignite coal in the Poplar River area. The life expectancy of the fuel supply is 35 years. The thickness of material overlying the coal (overburden) varies from 10 to 50 m (33 to 165 ft), averaging about 25 m (82 ft). Coal thickness varies from 1 to 5 m (3 to 16 ft), averaging about 3 m (10 ft). Topsoil will be removed to a depth of about 30 cm (1 ft) and stockpiled for later use in reclamation. Overburden will be removed and cast outside the mining area. The coal will be removed and hauled to the loadout facility for processing and shipment to the power plant by train.

7.1.1.1 Coal-Handling Facility

The coal-handling facility consists of a 200 tonnes (220 short tons) per hour coal breaker and conveyor system which carries the lignite to a 14 300 tonne (15,700 short tons) loadout stockpile at the mine site (Figure 7.2).

7.1.1.2 Maintenance Shop and the Fueling Area

The mine site also contains a number of ancillary structures required for maintenance and storage, as well as fuel storage and refueling areas (Figure 7.2).

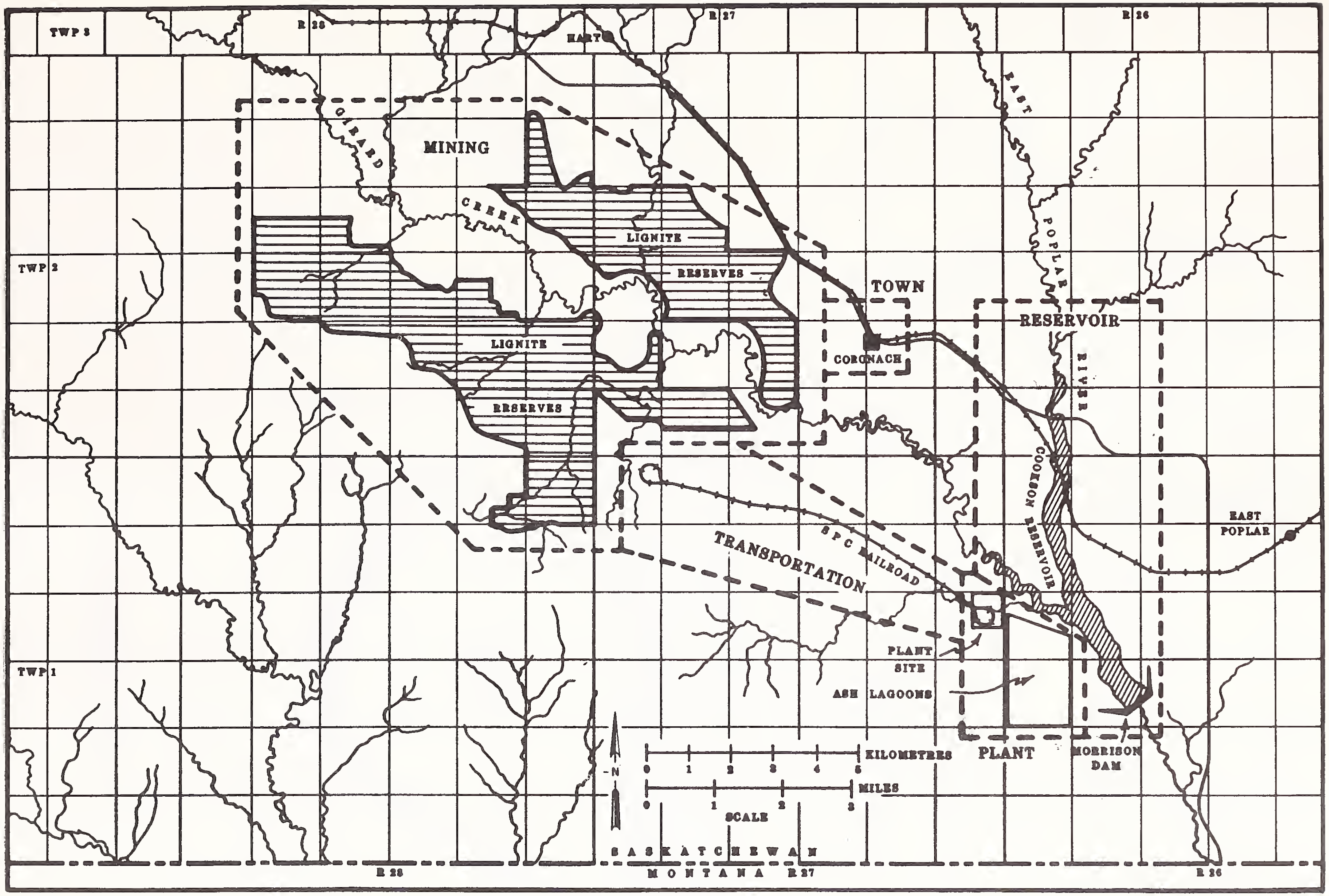

Figure 7.1 Major components of the Poplar River Power Project.

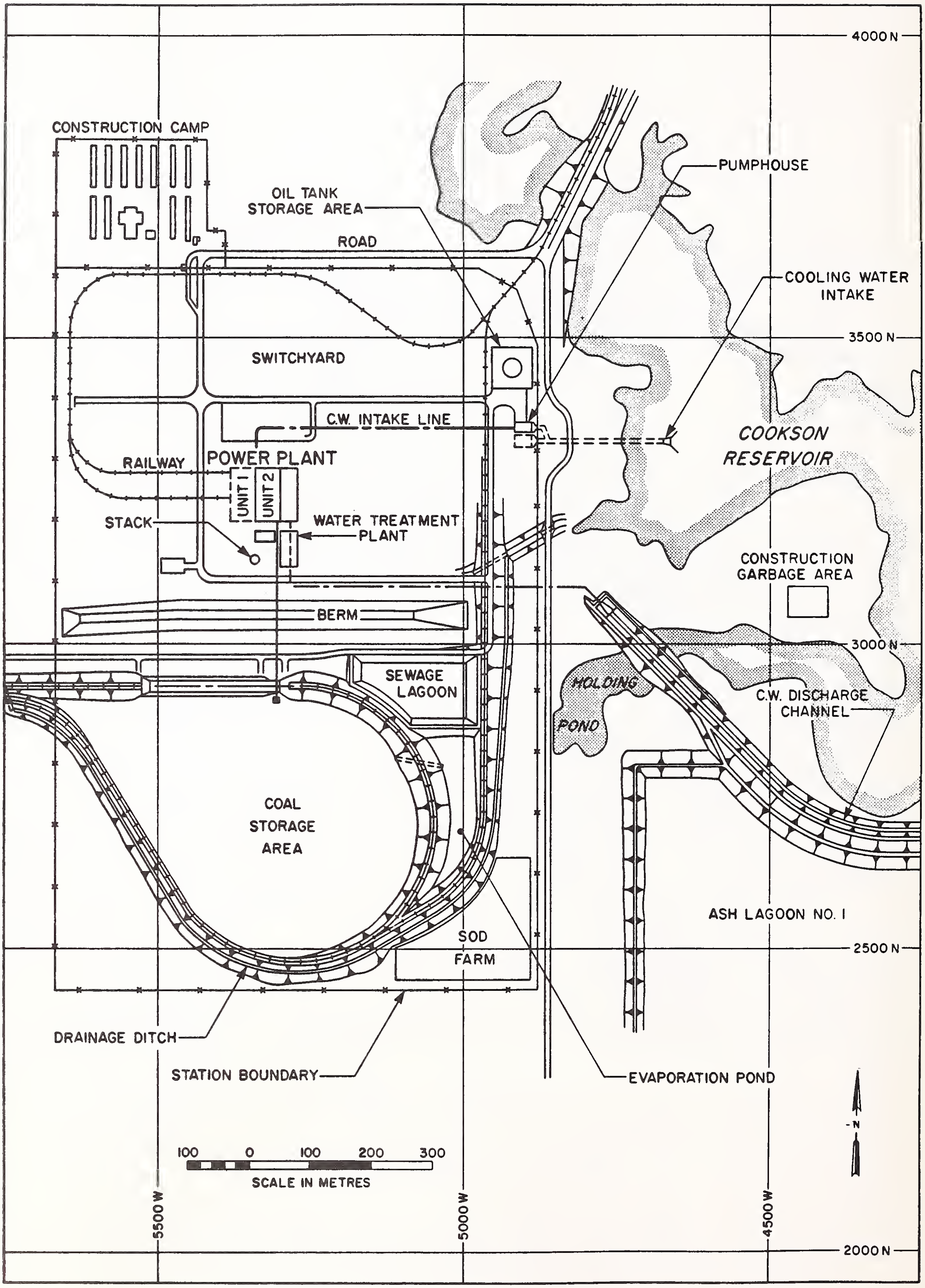

Figure 7.2 Layout of Poplar River generating station.

7.1.1.3 Mine Dewatering

In order to mine in relatively dry conditions, mine site dewatering commenced in the spring of 1976 and will continue through the life of the project. The dewatering wells discharge into Girard Creek and subsequently into Cookson Reservoir.

7.1.1.4 Surface Water Diversion

Natural drainage interrupted by mining activity will be diverted around the mine site to ensure that the water does not enter the pit. This water will be discharged to Girard Creek.

7.1.1.5 Mine Pit and Sump Water

The mine pit and sump water will be derived from seepage, direct precipitation, and spoil pile runoff. It will be pumped into a settling pond and then released to Girard Creek.

7.1.1.6 Runoff from Reclaimed Areas

Runoff from reclaimed areas will enter the same drainage systems that existed prior to mining.

7.1.1.7 Sanitary and Other Wastes

Sanitary wastes will be generated by facilities in the mine-services building and equipment-storage shed. Wastewater will also be generated by equipment-washing facilities. These wastes will be treated in a lagoon and disposed of by means of an effluent irrigation system. Consequently there will be no direct discharge to Girard Creek or Cookson Reservoir.

7.1.2 Transportation Systems

Transport systems at the mine site and power plant will provide for lignite haulage from the mine to the plant loadout site by unit train.

7.1.3 Power Plant

The major features of the power plant shown in Figure 7.2 are:

(i) powerhouse (including service bay)
(ii) stack and electrostatic precipitator
(iii) switchyard
(iv) water treatment plant
(v) coal storage and handling area
(vi) oil tank storage area
(vii) cooling system (including intake, pumphouse, discharge channel and outlet structure)
(viii) construction camp
(ix) holding pond

(x) evaporation pond

(xi) sewage lagoon

(xii) sod farm

Items (i) to (viii) are power station components while item (ix) to (xii) are waste disposal or containment facilities. Particular attention was paid to those aspects which could have a bearing on the water quality in Cookson Reservoir and the East Poplar River.

7.1.3.1 <u>Condenser Cooling Water System</u>

Condenser cooling water systems are used to condense spent steam from the turbines back to water so that it can be recirculated through the steam cycle. Approximately 50 percent of the heat produced in coal combustion is disposed of in the cooling water discharge.

The cooling system consists of a water intake in Cookson Reservoir, a pumphouse with three circulating pumps, a double pass condenser and a 3800 m (12,460 ft) channel which discharges just upstream of the dam.

7.1.3.2 <u>Auxiliary Cooling Water System</u>

Auxiliary cooling water for plant equipment such as hoppers, bearings and pumps is drawn from the condenser cooling water inlet line. Part of the auxiliary water is diverted for ash sluicing and cooling, water treatment plant supply, and a variety of other miscellaneous purposes. Water not so diverted is discharged to the main cooling water return.

7.1.3.3 <u>Water Treatment Plant</u>

The water treatment plant is comprised of conventional treatment components (for clarifica-ation and filtration), reverse osmosis demineralizing equipment, and demineralizing cation and anion units. The reverse osmosis system is to remove most of the dissolved mineral concentration and the ion exchange demineralizing plant is for final preparation of boiler feedwater.

7.1.3.4 <u>Outside Storm Drains and Roof Drains</u>

The drains collecting storm runoff from the station site area discharge directly into a ditch which empties into the reservoir northeast of the power plant. Roof drains discharge into the cooling water discharge pipe.

7.1.3.5 <u>Sanitary Wastes</u>

The power plant sanitary wastes will be treated in a system consisting of a package activated sludge plant, sewage holding lagoon and an irrigation system for the sod farm.

7.1.3.6 <u>Holding Pond</u>

Local runoff will be directed to a holding pond located just east of the coal storage area.

7.1.3.7 Reserve Coal Stockpile

Runoff from the coal held in the coal storage area is directed to an evaporation pond.

7.1.3.8 Live Coal Stockpile

The live coal stockpile is contained in an underground silo between the reserve coal pile and the power plant. Water draining from the live coal stockpile will be collected in transfer sumps and directed to the ash lagoons.

7.1.3.9 Ash Disposal System

The power plant will produce some 365 x 10^6 kg (510 x 10^3 short tons) of ash per year. Bottom ash which averages about 24 percent of the total ash is collected wet in the bottom ash hopper below the boiler. Fly ash, discharged to the stack, is dry collected by a 99.5 percent efficient electrostatic precipitator before reaching the stack. Present proposals require the bottom and fly ash to be slurried and pumped to a three-cell ash lagoon. The lagoon will eventually be expanded to seven cells in the general area shown in Figure 7.1. The proposed ash lagoon operation is to consist of filling the three cells in sequence, with the decant being released after one month of settling to Cookson Reservoir. The quality of the water in the lagoon will depend on the constituents dissolved from the ash into the slurry water.

7.1.4 Village of Coronach

Although not a part of the SPC power plant project, the village, and its potential effect on water quality, were taken under review by the Board because of expected increased population.

Consultants employed by the Village of Coronach have predicted a population of 1200 persons by the mid 1980s. Wastewater will be treated in a new multi-celled lagoon and disposed of by effluent irrigation. Consequently, there will be no direct effluent discharge from the village to Cookson Reservoir.

7.2 Effects on Surface Water Quality

The Board has reviewed the report of its Plant, Mine and Reservoir Operations Committee (Appendix E), which evaluated the quality of the effluents from the Coronach development, and the report of its Surface Water Quality Committee (Appendix A), which evaluated the effects of these effluents on the quality of the waters in the Poplar River system. The quality of the Poplar River can be affected by several of the plant and ancillary operations.

Mining operations have been examined in the following categories: dewatering, mine pit and sump drainage diversion around the mine site, discharge from reclaimed areas, sanitary and other wastes, and emissions to the atmosphere. The effects of planned transportation systems have also been evaluated.

The power plant operations which have been examined are: cooling water systems, the water treatment plant, plant roof and yard drains, reverse osmosis reject water, the ash disposal system, and stack emissions. The effects of the operation of Cookson Reservoir and the Village of Coronach were also included in the evaluation.

7.2.1 Discharges with Low Quantitative or Qualitative Significance

Seepage and precipitation into the active mining pit result in pit and sump drainage which contribute to surface and ground water discharges. In both cases, the quantity will be small, and the quality generally good, (e.g. TDS values of about 560 mg/L).

Diversions of surface drainage around mining operations will simply constitute a re-routing of relatively unaffected waters. Assuming that diversion water retention and settling facilities are provided, they will not contribute to changes in water quality.

The rates of non-point source discharges from reclaimed areas will vary according to the stages of the mining development. Post-mining runoff and sediment yields from reclaimed surfaces will increase greatly for a period, then will gradually return to pre-mining values in about the seventh year after the commencement of reclamation. Nevertheless, using assumptions consistent with the reclamation policies of SPC, it has been determined that water quality effects will not be significant in comparison with other factors.

Sanitary wastes, and wastes from mine shops and maintenance, will be treated and/or handled in such ways as not to alter significantly the quality of the receiving waters, because of requirements of the Saskatchewan departments of Health and Environment.

Atmospheric emission rates were estimated for various mining-related activities. The effects of material either directly or indirectly introduced to the river system from this source have been included later in the total atmospheric emissions analyses which also considered stack emissions.

Truck and train transportation will contribute water of runoff quality, except for insignificant exhaust emission products.

Plant roof and yard drains have also been considered in the total water budget of the development and on average will have no significant effect on the water quality of the receiving waters. However, unintentional releases of oil or other chemicals used at the plant site could enter the yard drains occasionally (Appendix E).

The Village of Coronach is considered to be an ancillary contributor of wastewater, inasmuch as its growth will be intensified as a result of the SPC development. All foreseeable municipal and industrial effluents to the reservoir have been examined and taken into account. Again, however, their individual and combined effects are not considered to be significant contributions to the river system.

Emissions from the Poplar River power plant stack, and fugitive dust emissions from both the plant and mining activities, will be deposited on surrounding land and water surfaces. For use in assessing the potential impact of these emissions on the water resources of the area, estimates were obtained for emission rates, resulting ground level concentrations, and deposition quantity. Using model techniques, deposition concentrations were estimated for the adjacent area. Figure 7.3 illustrates the results, using sulfur dioxide (SO_2) as an example. The estimated total addition of material directly to Cookson Reservoir from both stack emissions and fugitive dust from all adjacent activities is 6.3 g/cm^2/year (0.1 lb/sq in/year); this contributes about 1 mg/L increase in total solids, an insignificant increase. The corresponding estimated increase in boron is 0.0001 mg/L, also an insignificant amount. Estimates of total contributions to the river system from surface runoff were also determined to be of little significance.

Because of concern about possible adverse effects on agricultural uses, the Board also evaluated additions of selenium to the surrounding land from atmosphere emissions. The estimated increase is 0.0001 μg/g of soil which would not contribute significantly to surface water quality deterioration.

Chloride addition to the reservoir will come as a result of anti-fouling treatment and will vary irregularly according to seasonal requirements. This will result in a chlorine increase of about 110 kg/day (242 lbs/day) and a reduction in alkalinity (as calcium carbonate) of about 70 kg/day (154 lbs/day). These have been incorporated into the analyses of total effects, but separately are not significant.

The cooling water discharges will also contain material rejected from the reverse osmosis plant. This material will have a relatively high concentration of salts, about 2.5 times the concentration in the reservoir waters, and will contribute to their degradation. These effects have been included in the subsequent analysis of impacts to the river system.

The sources just described each contribute in some way to the total effects of the SPC operation at Coronach on the water quality of the Poplar River system. Even though they are each of slight consequence, their individual effects have been incorporated in the analysis of the total effects of the operation.

7.2.2 Discharges with Greater Quantitative or Qualitative Significance

The paragraphs below describe the effects of contributions which are of higher quantitative and/or qualitative natures.

7.2.2.1 Mine Dewatering

At the present time, the dewatering of the coal seam, by pumping of wells, produces about 130 L/s (4.6 cfs) of water which is transmitted to the surface water system. This will

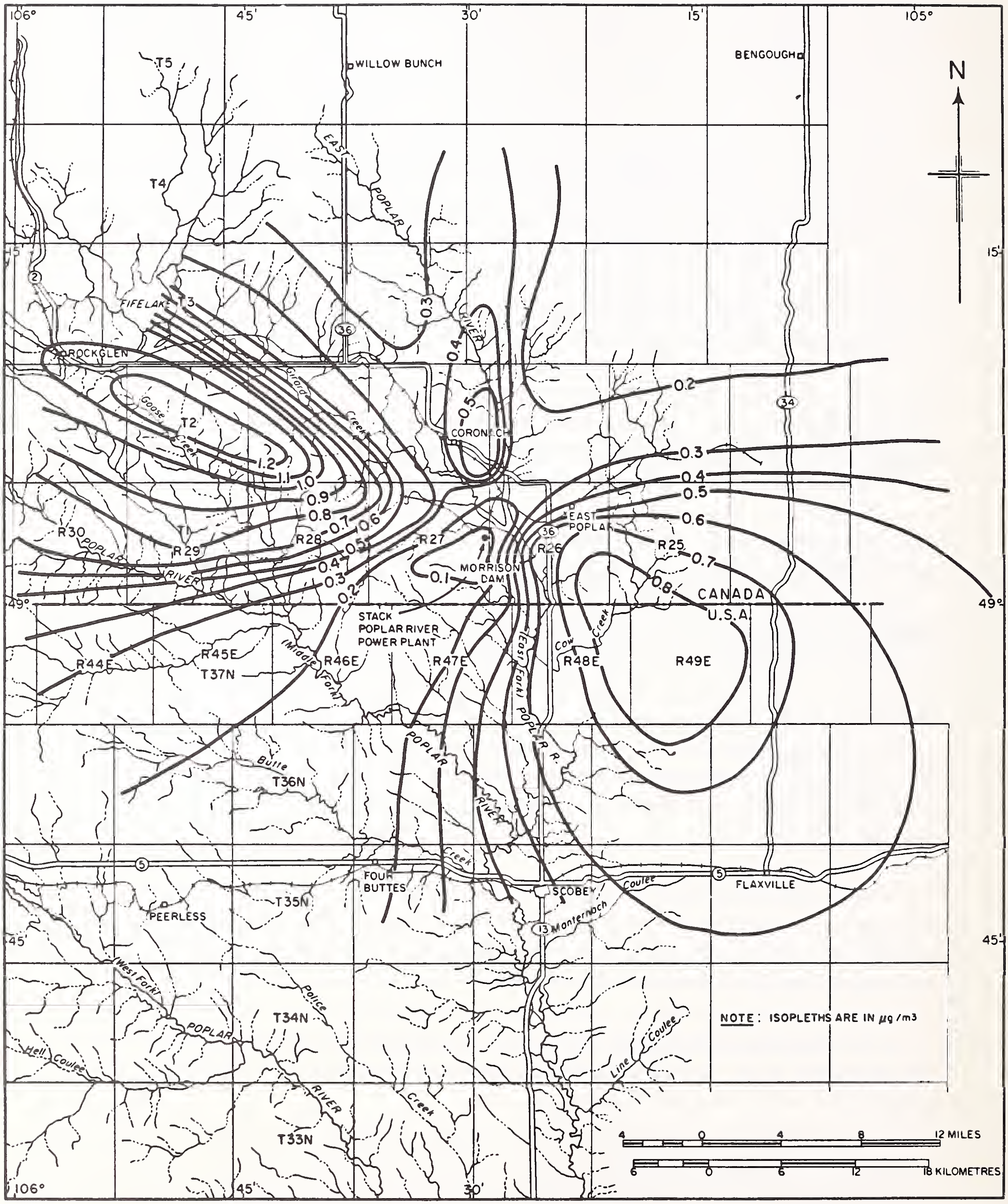

Figure 7.3 Isopleths of SO_2 mean annual concentration for 600 MW project.

decrease, reaching an estimated steady state volume of about 45 L/s (1.6 cfs). Boron concentrations are expected to be about 1.8 mg/L, and TDS is expected to be about 1100 mg/L.

7.2.2.2 Cooling Water Systems

Discharges from the condenser cooling water system and the auxiliary cooling system will contribute only chlorine and heat to Cookson Reservoir. These have been analysed according to various scenarios of cooling requirements. The maximum temperature rise, in the most severe conditions, is expected to be about 17C° (31F°) above ambient temperature of the reservoir. The discharge of a substantial volume of warm water may result in premature development and emergence of some insect species (fish food) and lower populations of these organisms. Warm water discharges in the April to May period will also affect fish spawning. Similar warm water discharges in midsummer are likely to have lesser effects, but could be lethal to game fish immediately below Cookson Reservoir. These findings on the biological resources of the river system have been evaluated in Appendix C.

7.2.2.3 Ash Disposal System

Ash residues from the development will be transported to settling lagoons adjacent to the reservoir. The water in these lagoons will be able to enter the river system in two ways. First, the lagoons will be managed in such a way that they will periodically be decanted into the reservoir. Second, the material situated under the lagoons will permit seepage into the river system.

Several operations contribute wastes to the ash lagoons. The ash residue will reach the lagoons in a slurry, which will constitute about 75 percent of the flow to the lagoons. The main boilerhouse sump, the water treatment plant, the boiler fireside and air preheater washing, discharge from the coal gallery drains, and occasional releases from the evaporation pond during high rainfall years, will constitute the remaining inputs.

The quality of the water to be expected in the ash lagoons, and the qualities of the decant and seepage waters, have been estimated through ash leaching tests. Early in the study, the Board recognized this aspect of the development as a point for focus of attention. The details of the analysis are contained in Appendix E.

Lagoon water quality depends in part upon the quality of the intake water. A summary, which assumes low quality intake water, is contained in Table 7.1. Although the chemical composition of the lagoons will vary, it has been determined that the ash slurry will contribute over 90 percent of the added concentration of many elements, including boron.

In order to verify the assumptions made in transforming ash leachate test results to ash lagoon water quality, an ash lagoon water quality study was conducted at the Boundary Dam

Table 7.1 INPUTS TO ASH LAGOONS AND TYPICAL LAGOON WATER QUALITY DURING AN EXTENDED DRY PERIOD

ELEMENT	QUANTITIES ADDED FROM WASTE STREAMS																			TYPICAL CONC. IN ASH LAGOONS*	
	ASH SLURRY (262.2 L/s)			MAIN BOILERHOUSE SUMP (68.2 L/s)			WATER TREATMENT PLANT (11.8 L/s)			FIRESIDE & PREHEATER WASHING (0.5 L/s)			COAL GALLERY WASHING (1.0 L/s)			ALL WASTE STREAMS (343.7 L/s)			AVG. INTAKE WATER CONC.	BEFORE EVAPORATION	AFTER EVAPORATION
	mg/L	kg/day	% of Total	mg/L	kg/day	% of Total	mg/L	kg/day	% of Total	mg/L	kg/day	% of Total	mg/L	kg/day	% of Total	mg/L	kg/day	% of Total	mg/L	mg/L	mg/L
Na	30	680	88.9	0			52	53	6.9	500	22	2.9	120	10	1.3	26	765	100.0	200	226	244
K	1.0	23	94.3	0			1.0	1.0	4.1				5	0.4	1.6	0.8	24.4	100.0	10	11	12
Ca	0	0	0.0	0			1.0	1.0	23.8				37	3.2	76.2	0.1	4.2	100.0	50	50	54
Mg	0	0	0.0	0			1.0	1.0	2.1	1000	43	91.7	34	2.9	6.2	1.6	46.9	100.0	50	52	56
HCO_3	-200	-4531	-101.6	0			72	73	1.6				0	0	0.0	-150	-4458	100.0	450	300	324
CO_3	40	906	100.0	0			0	0					0	0	0.0	31	906	100.0	0	31	33
SO_4	180	4078**	94.3	0			153	156	3.6	1200	52	1.2	440	38	0.9	146	4324	100.0	500	646	698
NO_3	0	0	0.0	0			1.0	1.0	100.0				0	0	0.0	0	1.0	100.0	10	10	11
Cl	5	113	90.0	0			12	12	9.5	5.0	0.2	0.2	5	0.4	0.3	4.2	125.6	100.0	20	24	26
SiO_2	4	91	98.5	0			1.0	1.0	1.1				4	0.4	0.4	3.1	92.4	100.0	10	13	14
B	10	227	99.0	0			1.0	1.0	0.4				15	1.3	0.6	7.7	229.3	100.0	5	13	14
Fe	0.5	11.3	14.8	0			0.04	0.04	0.0	1500	65	85.2	0.5	0.0	0.0	1.6	76.3	100.0	0.4	2.0	2.2

* Concentrations listed are based on a materials balances only. Certain elements, such as Mg and Fe, are likely to precipitate in actual operation.

** Sample computation: 262.2 L/s x 180 mg/L x 10^{-6} kg/mg x 86,400 s/day = 4078 kg/day.

(Saskatchewan) Generating Station, Unit No. 6. At Boundary Dam, Unit No. 6, which has an electrostatic precipitator with an efficiency of at least 95 percent, has been operating since November 1977. The results of this study suggest that, although there is a tendency for ash leachate tests to overestimate the rate of boron leaching to be expected in actual operation, the tests conducted on Poplar River ash provide adequate information to establish a range of potential leaching rates and are a reasonable approach to the determination of ash lagoon water quality.

A comparison of all leaching test results suggests that the rate of boron leaching from Poplar River ash will be higher on the average than from Boundary Dam ash. The range of concentrations of boron and other elements contained in Table 7.2 is considered indicative of the potential range of element additions in a once-through ash lagoon operation. The average values in Table 7.2 have been used (Appendices A and E) in a reservoir operation model to compute reservoir and border water quality on a monthly basis for an extended time period, and sensitivity of water quality to the high and low estimates has been evaluated (Appendix E).

Most of the ash lagoon water that will seep downward is expected to be transported to the East Poplar River below Morrison Dam. Some radial seepage to the mining area and the cooling water channel is also expected. Tests to determine the quality of water seeping downward through the ash in the lagoons were inconclusive and it has been assumed that this water would have a quality similar to that predicted for standing water in the lagoons. There is uncertainty as to the degree of attenuation of trace elements likely to occur in soils along the seepage path from the lagoons to adjacent surface waters. Typically, certain species have a strong tendency to be adsorbed by soil while others do not, the nature of the soil being a major factor. In modelling reservoir and International Boundary water quality, it has been conservatively assumed that no attenuation will occur. Recent adsorption tests using soil from the area of the proposed Poplar River ash lagoons have shown that the soil has some capacity for boron adsorption, suggesting that concentrations in ash lagoon seepage waters will be somewhat lower than the worst case assumption of no attenuation. The relative influence of major effluent discharges to the reservoir are summarized in Table 7.3

7.2.2.4 Reservoir Operation

In addition to the sources described above, a number of factors pertaining to the characteristics and operation of Cookson Reservoir will also affect the water quality of the East Poplar River.

An analysis of these has taken into account:

(i) natural inflow from the East Poplar River and Girard Creek;

(ii) leachates from the soil inundated by the reservoir;

Table 7.2 Range of Effluent Quality Expected to be Added from Ash Lagoon (mg/L)

Element	Low Estimate	Average Estimate	High Estimate
Na	20	30	65
K	1	5	10
Ca	0	0	100
Mg	0	0	10
B	6	10	15
HCO_3	-200	-100	0
CO_3	30	40	55
SO_4	100	180	240
NO_3	0	1	2
Cl	3	5	20
TDS (computed)	4	160	445

Table 7.3 COMPARISON OF LOADINGS FROM DIFFERENT EFFLUENT SOURCES

EFFLUENT SOURCE	AVG. ANNUAL FLOW (L/s)	CONCENTRATION ADDITIONS			CONTRIBUTION TO RESERVOIR[1]		
		Fe (mg/L)	B (mg/L)	TDS (mg/L)	Fe (Kg/yr)	B (Kg/yr)	TDS (Kg/yr x 10^6)
1 UNIT							
Mine Dewatering							
- low rate	43	(2.0)[2]	- 0.3	400	(2,710)	- 410	0.54
- high rate	100	(2.0)	- 0.3	400	(6,310)	- 950	1.26
Ash Lagoon Decant							
- low leaching rate	150	0.0	6.0	0	0	28,400	0
- avg. leaching rate	150	0.0	10.0	160	0	47,340	0.76
- high leaching rate	150	0.0	15.0	440	0	71,000	2.08
Ash lagoon Seepage - Once Thru	4	0.0	10.0	160	0	1,260	0.02
Ash Lagoon Seepage - Recirc.	1.5	(1.0)	48.0	3,850	(47)	2,270	0.18
Fireside and Preheater Washing	0.25	1,500	(50.0)	10,000	11,830	(390)	0.08
Equiv. Contribution from Net Nat. Evap.						25,000[3]	8.23
Equiv. Contribution from Forced Evap.						5,000	1.65
2 UNITS							
Mine Dewatering							
- low rate	43	(2.0)	- 0.3	400	(2,710)	- 410	0.54
- high rate	100	(2.0)	- 0.3	400	(6,310)	- 950	1.26
Ash Lagoon Decant							
- low leaching rate	309	0.0	6.0	0	0	58,510	0
- avg. leaching rate	309	0.0	10.0	160	0	97,510	1.56
- high leaching rate	309	0.0	15.0	440	0	146,270	4.29
Ash Lagoon Seepage - Once Thru	6	0.0	10.0	160	0	1,890	0.03
Ash Lagoon Seepage - Recirc.	1.5	(1.0)	48.0	3,850	(47)	2,270	0.18
Fireside and Preheater Washing	0.5	1,500	(50.0)	10,000	23,670	790	0.16
Equiv. Contribution from Net Nat. Evap.						25,000	8.23
Equiv. Contribution from Forced Evap.						12,000	3.95

[1]Kg/yr = (L/s) x (mg/L) x 31.5576

[2]Bracketed ( ) numbers are assumed based on limited information.

[3]Contribution from concentration due to evaporation are based on a full reservoir and initial TDS and B levels of 1000 mg/L and 3 mg/L respectively.

L/s x 15.8 = gal/min (US)

Kg x 2.2 = lbs

(iii) chemicals added to the reservoir in the lime-softening process;
(iv) overflows from Fife Lake.

Water losses from the reservoir include:

(i) releases through the riparian outlet and spillway at Morrison Dam;
(ii) seepage through and beneath Morrison Dam;
(iii) leakage around Morrison Dam through the Empress Group sands and gravels;
(vi) natural evaporation losses; and
(v) forced evaporation losses.

Although an initial contribution to TDS levels from recently inundated lands is thought to have occurred during the filling of the reservoir, the effects of this contribution were concluded to be of very short-term duration. No further effects on the reservoir quality are expected.

Lime softening has been suggested as a possible measure for condenser scale control. For purposes of this report, lime softening is treated as a possible mitigation alternative for TDS, and is included in Chapter 10. However, it should be noted that lime softening will probably cause slight increases in SAR.

Fife Lake forms a large natural storage area in the upper part of Girard Creek basin. Because of the small quantity of annual inflow and the large surface area for concentration due to evaporation, the quality of water in Fife Lake is poor. A small control structure at the outlet of the lake prevents releases downstream into Girard Creek. In the occasional year some overflow does occur. Fife Lake overflowed in both 1975 and 1976 and both overflows were noted to have a substantial effect on downstream water quality. The 1975 overflow occurred before Morrison Dam was completed and passed on down the East Poplar River. The 1976 overflow was retained in Cookson Reservoir and affected the quality of water in the reservoir during the first year of reservoir filling. Estimates of Fife lake water quality are included in Appendix A.

The reservoir not only reduces the immediate, poor quality effects of Fife Lake overflows, but may also extend effects of a less serious nature over a longer period of time, unless overflows are passed directly downstream by dam releases coinciding with overflows.

Releases from the reservoir to the East Poplar River will be in accordance with apportionment requirements as may be agreed upon by the United States and Canada. The Board has evaluated the water quality effects of those expected outflows, using the provisions of the apportionment presently recommended by the IJC. These have been summarized in Chapter 6.

Some seepage around Morrison Dam to the river will occur. This water is assumed in the worst case to be of reservoir quality.

Evaporation losses from the reservoir, including both natural and forced, will be of considerable significance to the water quality of the East Poplar River. Because of uncertainties in the state of the art of estimating evaporation, several independent estimates were obtained and carefully assessed. These are fully discussed in Appendix E. The net natural evaporation from Cookson Reservoir will average about 0.6 m (2 ft) annually, with mean monthly values in late summer reaching about 0.2 m (0.7 ft). Based on a full reservoir in spring, this means an average annual water loss of 6865 dam^3 (5,565 ac-ft) or 17 percent of the full reservoir volume. The comparable value of forced evaporation for two-unit operation is 3300 dam^3 (2,765 ac-ft) or 8 percent of the full reservoir volume. The effects of evaporation on reservoir water quality, by increasing TDS, has been incorporated in the net effects of the SPC development on the water quality of the Poplar River system (Table 7.3). The order of magnitude of effects of evaporation on total dissolved solids and boron, based on a full reservoir, are also contained in Table 7.3.

7.2.3 Summary of Effects of the SPC Operation

The Surface Water Quality Committee of the Board has taken the findings of the Plant, Mine and Reservoir Operations Committee (Appendix E) in regard to the contributions to the water quality of Cookson Reservoir and the East Poplar River by the SPC development and ancillary operations, and has evaluated the consequent effects. This was accomplished through the use of several mathematical models described in Section 3.1.4. Appendix A contains the results from analysis of these several combinations of conditions.

Two examples of predicted results are presented in this report, using boron and TDS. Predicted values of these constituents for the East Poplar River at the International Boundary, near Scobey, south of Scobey but above the confluence of the Poplar and West Poplar rivers, and near Poplar, Montana, are shown for the following scenarios (Tables 7.4 - 7.11):

- historical baseline
- 1 power unit with uses for the year 1975 in both countries
- 2 power units with uses for the year 1985 in both countries, and with apportionment provisions in effect, except that Canada does not retain unused water, and
- 2 power units with uses for the year 1985 in Canada and for the year 2000 in the United States, and with full apportionment (Canada uses its total share).

It should be noted that use projection analyses have revealed no significant expected changes in Canadian usage, under apportionment, between the years 1985 and 2000.

Table 7.4 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on TDS Concentrations of East Poplar River at International Boundary

Scenario	Statistic	Concentration of TDS mg/L											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1470	1290	250	340	560	640	680	770	720	700	830	1070
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	980	970	930	880	920	910	920	950	960	990	990	970
	Percent change from baseline	-33	-25	270	160	64	42	35	23	33	41	19	-9
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	1100	1070	990	940	960	980	990	1020	1050	1090	1060	1080
	Percent change from baseline	-25	-17	300	180	71	53	46	33	46	56	28	1
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	1090	1080	990	950	970	1010	1010	1050	1050	1060	1060	1090
	Percent change from baseline	-26	-16	300	180	73	58	49	36	46	51	28	2

Table 7.5 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on Boron Concentrations of the East Poplar River at International Boundary

Scenario	Statistic	Concentration of Boron mg/L											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	2.9	2.5	0.3	0.5	1.0	1.2	1.3	1.4	1.3	1.3	1.6	2.1
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	6.5	6.1	4.2	3.8	4.1	4.2	4.9	5.0	4.7	4.6	4.9	5.4
	Percent change from baseline	120	140	1300	660	310	250	280	260	260	250	210	160
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	12.0	11.1	6.4	5.5	6.8	7.5	8.1	8.7	8.2	7.8	8.0	9.7
	Percent change from baseline	310	340	2030	1000	580	530	520	520	530	500	400	360
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	11.5	10.9	6.4	5.4	6.8	7.3	8.1	8.6	8.3	7.0	7.7	9.6
	Percent change from baseline	300	340	2030	980	580	510	520	510	540	440	380	360

Table 7.6 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on TDS Concentrations of East Poplar River near Scobey, Montana

		Concentration of TDS mg/L											
Scenario	Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1250	1170	410	490	680	750	790	850	800	790	880	1070
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	980	980	630	780	900	900	930	970	960	970	1020	990
	Percent change from baseline	-22	-16	54	59	32	20	18	14	20	22	16	-8
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	1100	1050	640	820	940	950	970	1020	1010	1010	1010	1080
	Percent change from baseline	-12	-10	56	67	38	27	23	20	26	28	15	1
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	1100	1050	660	800	940	940	980	1070	1020	1010	1090	1100
	Percent change from baseline	-12	-10	61	63	38	25	24	26	28	28	24	3

Table 7.7 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on Boron Concentrations of the East Poplar River near Scobey, Montana

		Concentration of Boron mg/L											
Scenario	Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	2.5	2.2	0.7	0.8	1.2	1.3	1.4	1.5	1.4	1.4	1.6	2.0
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	6.4	6.0	1.5	2.3	3.0	3.2	3.9	4.1	3.7	3.2	4.3	5.2
	Percent change from baseline	160	170	110	190	150	150	180	170	160	130	170	160
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	11.8	10.7	1.5	2.7	4.6	5.3	6.3	6.7	6.0	4.9	6.9	9.1
	Percent change from baseline	370	390	110	240	280	310	350	350	330	250	330	360
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	11.1	10.6	1.5	2.6	4.4	5.0	6.1	6.6	5.7	4.8	6.6	8.3
	Percent change from baseline	340	380	110	230	270	280	340	340	310	240	310	320

Table 7.8 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on TDS Concentrations of Poplar River South of Scobey above Confluence with the West Poplar River

Concentration of TDS mg/L

Scenario	Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1250	1250	480	510	690	750	780	960	930	900	960	1150
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	1120	1090	530	580	740	820	840	1010	1060	1000	1050	1100
	Percent change from baseline	-10	-13	10	14	7	9	8	5	14	11	9	-4
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	1180	1140	530	590	760	830	880	990	1090	1020	1050	1110
	Percent change from baseline	-6	-9	10	16	10	11	13	3	17	13	9	-3
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	1190	1140	610	620	780	840	710	-	-	1080	1080	1150
	Percent change from baseline	-5	-9	27	22	13	12	-9	-	-	20	13	0

Table 7.9 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on Boron Concentrations of Poplar River South of Scobey above Confluence with the West Poplar River

Concentration of Boron mg/L

Scenario	Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1.7	1.7	0.7	0.8	1.1	1.2	1.3	1.5	1.5	1.5	1.5	1.8
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	3.7	4.1	0.9	1.2	1.5	1.7	1.9	2.7	2.9	2.3	2.3	2.6
	Percent change from baseline	120	140	29	50	36	42	46	80	93	53	53	44
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	5.8	6.3	0.9	1.2	1.8	2.3	2.4	3.1	3.7	2.8	2.8	3.5
	Percent change from baseline	240	270	29	50	67	92	85	110	150	87	87	94
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	5.2	5.9	1.0	1.2	1.7	2.2	1.6	-	-	2.8	2.8	3.3
	Percent change from baseline	210	250	43	50	55	83	23	-	-	87	87	83

Table 7.10 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on TDS Concentrations of Poplar River near Poplar, Montana

Scenario	Statistic	Concentration of TDS mg/L											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1240	1280	470	510	700	790	1020	1230	1250	1010	1010	1190
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	1170	1190	490	520	730	810	1020	1250	1230	1070	1030	1160
	Percent change from baseline	-6	-7	4	2	4	3	0	2	-2	6	2	-3
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	-	-	-	440	690	770	1000	1320	1250	-	-	-
	Percent change from baseline	-	-	-	-14	-1	-3	-2	7	0	-	-	-
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	-	-	-	390	590	770	1010	1360	1360	-	-	-
	Percent change from baseline	-	-	-	-23	-16	-3	-1	11	9	-	-	-

Table 7.11 Summary of Impact of Saskatchewan Power Corporation's Poplar River Thermal Generating Plant on Boron Concentrations of Poplar River near Poplar, Montana

Scenario	Statistic	Concentration of Boron mg/L											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Historical Baseline	Median	1.3	1.3	0.5	0.6	0.9	0.9	0.9	1.0	1.0	1.2	1.2	1.3
1 power unit. Levels of water use: year 1975 in both Canada and the U.S.	Projected Median	2.5	2.6	0.6	0.8	1.1	1.1	1.0	1.2	1.4	1.5	1.6	1.7
	Percent change from baseline	92	100	20	33	22	22	11	20	40	25	33	31
2 power units. Levels of water use: year 1985 in both Canada and the U.S.	Projected Median	-	-	-	0.8	1.2	1.3	1.1	1.0	1.7	-	-	-
	Percent change from baseline	-	-	-	33	33	44	22	0	70	-	-	-
2 power units. Levels of water use: year 1985 in Canada; year 2000 in the U.S. Full water apportionment.	Projected Median	-	-	-	0.9	1.1	1.2	1.0	1.0	1.0	-	-	-
	Percent change from baseline	-	-	-	50	22	33	11	0	0	-	-	-

East Poplar River at the International Boundary

With a progression towards full development (Scenarios 3 and 4) there will be increases in TDS concentrations over historical baseline concentrations with the exception of the winter months, when some reductions are predicted. These will be due to the influence of Cookson Reservoir which essentially reduces flow, and water quality fluctuations. The historical dilution effect of snowmelt during March will not be observable because of the dampening influence of Cookson Reservoir. Boron concentrations significantly increase with all scenarios over historical baseline concentrations, with a fivefold increase during the critical summer irrigation season. Like TDS, boron concentrations change insignificantly in comparing full development with less than full implementation of apportionment.

East Poplar River Near Scobey, Montana

TDS concentrations with full development (Scenario 4) do not increase over historical baseline conditions at the same magnitude as the upstream station. Most monthly concentrations do not exceed historical baseline conditions by more than one third. Again, there is improvement in TDS concentrations in winter months, but less improvement during spring snowmelt because of Cookson Reservoir. Seasonally, boron concentrations at this station show a characteristic improvement from low winter flows to high spring runoff periods. When comparing predicted data with historical baseline data, monthly highs and lows coincide, but generally a threefold to fourfold increase is indicated for all months. In comparison with the upstream station, boron concentrations generally decrease.

Poplar River South of Scobey Above Confluence with the West Poplar River

At full development, TDS concentrations will increase by about 25 percent above historical baseline conditions for March and April when concentrations are lowest. The dilution effects of inflow into the system in this locality serves to preclude further deterioration. Boron concentrations are similarly reduced by dilution at this point, although full development results in significant winter increases.

Poplar River Near Poplar, Montana

The impact of full development is much less obvious at this station than at the three upstream stations. Inflows of major tributaries mask any significant deterioration or improvement which occurs at upstream stations. There is a general decrease in boron concentrations and a general increase in TDS concentrations from the headwaters to the mouth.

7.3 Expected Effects of SPC Plant on Ground Water Quality

7.3.1 Mathematical Models of Ground Water Flow

The ground water system of the upper Poplar River basin is very complex. Thus, it was necessary to use mathematical models to simulate its long-term behavior in response to

coal-seam dewatering and operation of Cookson Reservoir. For modelling purposes, the geological formations listed in Table 2.1 were classified into five principal aquifer layers in Table 7.12.

The water storage and transmitting properties were estimated for each layer on the basis of information from other sources taken from published reports. These values are presented and their derivation discussed in Appendix B.

Table 7.12 GENERALIZED AQUIFER LAYERS OF THE UPPER POPLAR RIVER BASIN

Layer	Canada	United States
5	Valley-fill alluvium, glacial deposits, and Wood Mountain Formation	Valley-fill alluvium, glacial deposits, and Flaxville Formation
4	Upper Ravenscrag Formation	Upper Fort Union Formation
3	Hart Coal Seam	Lignite, horizon D (Collier, 1925)
2	Lower Ravenscrag Formation	Lower Fort Union Formation and Upper Hell Creek Formation
1	Frenchman Formation	Lower Hell Creek Formation and Fox Hills Sandstone

The models were used to simulate the behavior of the ground water system in the East Poplar River basin, and to predict responses to future SPC plant operations. The first model applied only to the Hart Coal Seam aquifer. It was used to evaluate the combined effects of dewatering and expected leakage from adjacent aquifers into this aquifer.

This model demonstrated that the effects of natural ground water recharge from precipitation and snowmelt will reduce the spread of the area in which ground water levels decline as a result of dewatering. It is difficult to specify exactly how much water will infiltrate from this source, but the model showed that an increase from 3.5 to 21.5 mm/year (0.33 to 1 in/year) should reduce the area affected from about 115 km^2 (46 mi^2) to about 60 km^2 (23 mi^2). The 21.5 mm/year (1 in/year) infiltration figure represents about 6 percent of the average precipitation in the area. Experience has suggested that this percentage is a good approximation of normal infiltration in southern Saskatchewan.

A second and more detailed mathematical simulation model was prepared to predict ground water level changes due to coal seam dewatering and to the influence of Cookson Reservoir.

This model took into account all of the aquifers listed in Table 7.12, their interrelationships, and their interconnections with surface water bodies.

The model was tested by comparing simulated changes in ground water levels with actual changes observed during the period from spring 1976 to fall 1977. During this period, 12 dewatering wells discharged water from the Hart Coal Seam into Girard Creek, and from there it flowed downstream to Cookson Reservoir. The impoundment of water in the reservoir during this same period raised the water level in the reservoir by 7 m (23 ft). Both the recorded rates of discharge from the dewatering wells and the water level changes in the reservoir were incorporated into the model to make the simulation more realistic. The model was adjusted until there was reasonable agreement between the simulated and observed water levels.

The simulated and measured changes are shown in Figure 5.3. The model in this form was then used for predicting long-term ground water level changes resulting from the SPC power plant operation.

The proposed mining plan subdivides the area to be mined into 13 blocks (Figure 7.1). Block 1 is scheduled to be mined in the first 5-year period, and the remaining 12 blocks will be mined successively in pairs over succeeding 5-year periods. Thus, the projected length of the mining operation is 35 years, ending in 2014, if plant operation begins in 1980. In the application of the second ground water model, it was assumed that the dewatering wells would operate at a steady rate throughout each 5-year period of mining. However, the rates were varied from 5-year period to 5-year period in order to ensure adequate removal of water from each block as it was being mined.

The model simulated the effects of seven 5-year periods of pumping, followed by three periods of recovery for 10, 10, and 20 years. Thus, the total duration of the simulation period is 75 years. The predicted pumping and depletion of ground and surface water sources is shown in Figure 7.4. Greatest stream depletion is for Girard Creek during the two periods of heaviest pumping. This is because Girard Creek is located close to the pumping wells. Continued surface water depletion is mostly due to Cookson Reservoir.

As shown in Figure 7.4, the maximum effect on ground water storage due to dewatering will occur at the end of the last pumping period. Moreover, the maximum decline in ground water levels also will occur at this time.

Predicted effects in the upper Ravenscrag Formation are especially interesting because many wells in Montana are completed in this layer. The predicted area for which water levels in the upper Ravenscrag will decline significantly, as a result of dewatering, extends southward from Fife Lake to northern Montana. Maximum water level decline predicted for this formation in Montana is 0.7 m (2.3 ft) near the International Boundary due south of the area to be

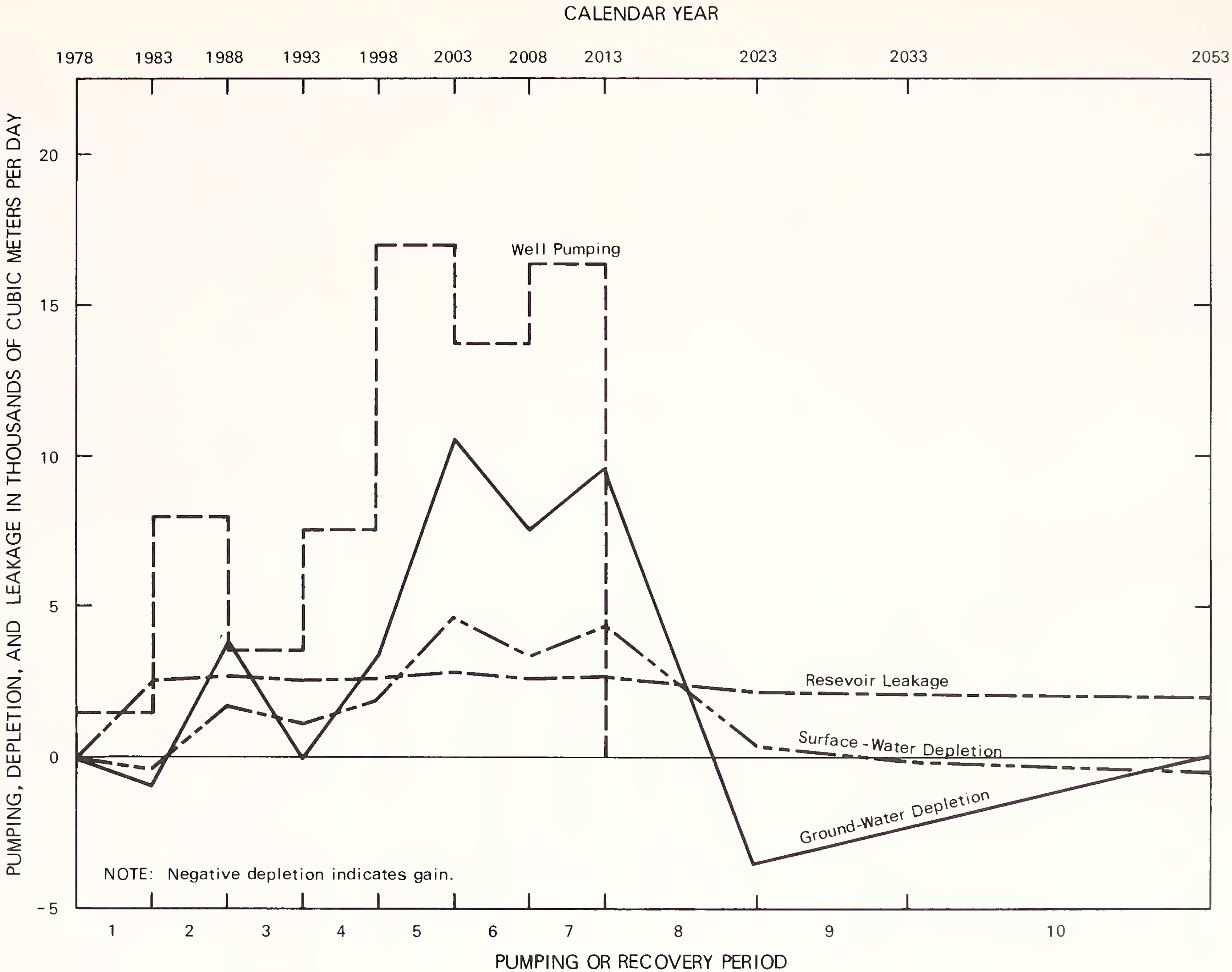

Figure 7.4 Predicted pumping, depletion, and leakage, upper Poplar River basin, Saskatchewan and Montana.

strip mined. In contrast, the predicted maximum rise in water levels in the upper Ravenscrag Formation due to 75 years of leakage from Cookson Reservoir is about 0.1 m (4 in) near the area where the East Poplar River crosses the International Boundary.

For the Hart Coal Seam and the underlying Ravenscrag and Frenchman Formations, the patterns of declines and rises are similar to those for the upper Ravenscrag except that the effects of streams, Cookson Reservoir, and Fife Lake are subtle because of the depth of these layers beneath the surface water sources. All ground water levels will begin to recover after the last pumping period, that is, the lowering of the water levels will gradually reduce with time. Forty years after the SPC power plant has ceased operation, the maximum predicted residual water level declines will occur in the mined area west of Girard Creek, in Saskatchewan, as follows:

Layer	Maximum residual decline (m)
Valley-fill alluvium, glacial deposits and Wood Mountain Formation	4.1 m (13.4 ft)
Upper Ravenscrag Formation	2.2 m (7.2 ft)
Hart Coal Seam Formation	2.1 m (6.9 ft)
Lower Ravenscrag Formation	1.5 m (4.9 ft)
Frenchman Formation	1.1. m (3.6 ft)

In the absence of renewed pumping the water levels will rise with time.

Additional model tests were made to determine the importance of uncertainties in model data, model errors, and possible changes in stream and reservoir management. A detailed description of these model tests can be found in Appendix B. The resulting changes as predicted by the models were minor in Saskatchewan and negligible in Montana.

In conclusion, the SPC Power Plant and the surrounding areas are underlain by a series of interconnected aquifers. Plant operations will require dewatering wells that will be pumped for 35 years as well as a surface reservoir for plant cooling purposes. The dewatering wells will remove water from the Hart Coal aquifer and inflow from Cookson Reservoir will recharge a valley-fill aquifer. Lowering of the water level in the coal aquifer is sensitive to recharge from adjacent aquifers. Long-term dewatering by wells and infiltration from the reservoir will cause changes in the water levels in all aquifers that lie above the Bearpaw Formation in the SPC plant region. These changes will be

counteracted to some extent as a result of infiltration from precipitation and snowmelt. Water level declines will slowly recover and surface water depletion will slowly diminish for many years following the cessation of pumping. Water level rises and streamflow gains due to Cookson Reservoir will continue as long as the reservoir remains intact and leaks into the valley-fill alluvium.

7.3.2 Potential Effect of SPC Operations on Ground Water Chemical Quality

In evaluating the effects of the SPC plant on ground water quality, Cookson Reservoir, the ash lagoons, and ancillary mine operations were considered.

7.3.2.1 Cookson Reservoir

The potential impact of the reservoir on the ground water chemical quality is expected to be extremely dependent on the capacity of the aquifers to prevent alteration or variation in the chemical quality of infiltrating water. Prior to the filling of Cookson Reservoir, infiltrating water was mainly snowmelt, a fresh water with a relatively low pH (5.5 to 6.5) compared to most ground waters in the area. The ability of subsurface systems to alter the chemical composition of the snowmelt water is obvious, since the chemical composition of ground water is considerably different. The chemical quality of the reservoir water is more like that of the ground water than that of average snowmelt water.

If chemical reaction rates are sufficiently slow, the part of the ground water system likely to be most significantly affected by Cookson Reservoir will be the subsurface flow around and beneath Morrison Dam. The springs and seepage on the immediate downstream side of the dam would eventually acquire a chemical quality similar to that of Cookson Reservoir. On the basis of other studies, it is unlikely that the overall chemical composition of the seepage water would vary significantly from that of normal ground water. However, the more conservative substances, such as nitrate, will tend to approach reservoir concentrations in both the near-dam seepage and in the shallow ground water flow system.

The water temperature increase due to the reservoir will have a negligible effect on chemical reactions in the ground water systems. The use of isotope data revealed that most of the present seepage from Cookson Reservoir is ground water being forced downstream from the reservoir at much higher flow rates than normal because of the increased hydraulic head imposed by the reservoir. The most noticeable effect will be in the shallow aquifer near Cookson Reservoir where the ground water is generally of lower salinity than the reservoir water.

7.3.2.2 Ash Lagoons

The presently proposed location of the ash lagoons is southwest of Cookson Reservoir. The till in that area is heterogeneous, and contains coarse-grained and permeable zones. The presence of these zones emphasizes the need for some type of lagoon lining for retention of potential contaminants found in the ash-lagoon water. The water from the ash lagoon will

not only be of poorer chemical quality (higher concentrations of most chemical constituents) than the reservoir or normal ground water, but also may have significant concentrations of other constituents, notably boron.

Water entering the lagoons with the slurry will have a high alkalinity. This will be reduced both in the lagoon and during the downward movement of ash-lagoon water into and through the underlying till. The reduction in alkalinity will lead to the removal of some constituents as a result of chemical precipitation. Others will be subject to adsorption on the solid particles that make up the till. Recent evidence suggests that at least some of the boron may be removed from the ground water in this way.

It is expected that ash-lagoon leakage will be primarily downward with subsequent movement through the Empress Group aquifer. Discharge to surface water would be principally to the East Poplar River below Morrison Dam. Because of the higher water levels in the ash lagoons, however, some of the subsurface leachate from the lagoons will be diverted towards and will flow into Cookson Reservoir. The likely directions of subsurface water movements are shown in Figure 7.5.

A number of estimates have been made of the rate of ash lagoon leakage and of the contribution it will make to flow and chemical water quality in the East Poplar River below Morrison Dam. These estimates can be found in Appendices B and E. The seepage rates are based on the best information available on the permeabilities of the till and underlying Empress Group sand and gravel layer. Adequate information is not available on the vertical permeability of the till and the estimated downward seepage rate may be higher than will actually occur.

According to the various estimates, the eventual inflow of leachate from a single lagoon into the river in the critical stretch below Morrison Dam could be as much as 17.4 L/s (0.6 cfs). For a combination of lagoons, the maximum estimated leachate inflow is therefore comparable to natural mean monthly flows in the East Poplar River during some of the low-flow winter months. It should be noted that although no time delay was assumed in the reservoir operational model, the actual arrival of leachate at the river could be delayed for some tens of years. Despite the relatively high permeabilities assumed, the rate of ground water movement and the advance of the contaminated zone will be very slow, as is indicated in Figure 7.5.

In summary, there could be a threat to water quality in the East Poplar River below Morrison Dam because of the infiltration of ash-lagoon leachate into the subsurface and subsequent movement towards and into the river. The actual arrival of the leachate at the river will be delayed, possibly for some tens of years, because of slow rates of ground water movement. The estimated rates of inflow into the river and thus the effects on river

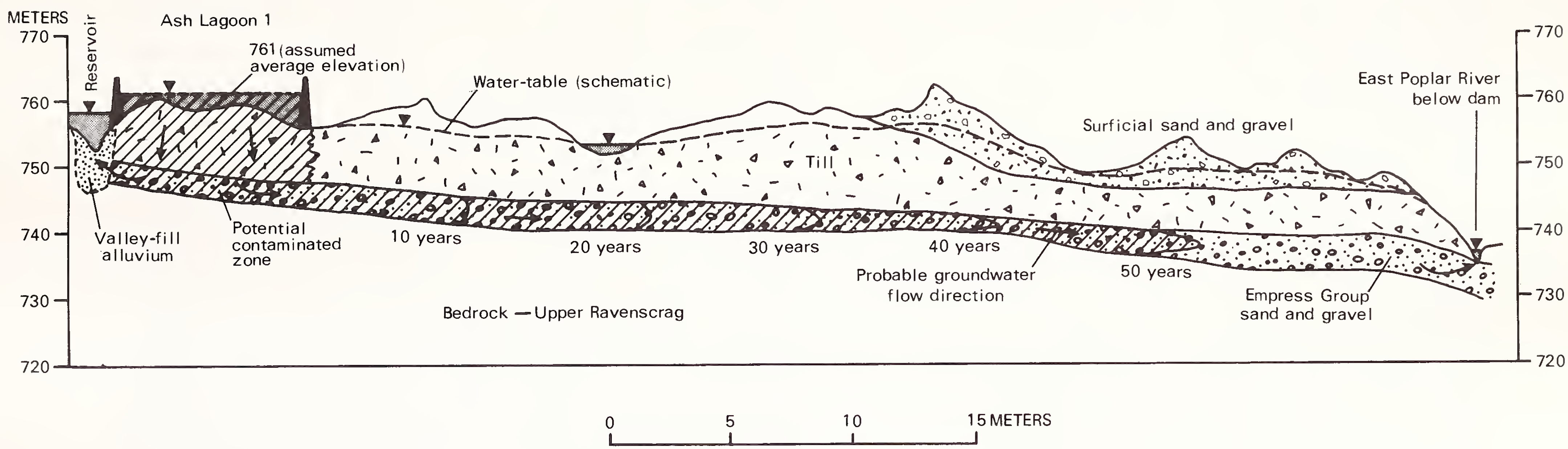

Figure 7.5 Schematic diagram of potential subsurface contamination from ash lagoon leakage. Arrows show probable direction of water movement.

water quality likely represent exaggerations of the real situation because the assumptions made represent various least favorable combinations of circumstances. Movement of leachate via the subsurface route does, however, in at least one respect, represent a favorable circumstance. Chemical reactions and adsorption of dissolved constituents onto aquifer materials will tend to remove some of these constituents from the leachate. There now appears to be a reasonably good chance that boron will be affected in this way.

Although there is a considerable range of uncertainty associated with the attempts to estimate lagoon leakage and its effects, the results nevertheless indicate that the question of lagoon leakage is an important one. It is believed that dealing with the problem adequately will require both mitigation and surveillance.

7.3.2.3 Ancillary Mine Operations

Other potential sources of ground water contamination include the coal storage piles, the plant sewage lagoon and associated sod-farm effluent spray irrigation operation, the evaporation pond, the holding pond, transformer leakage, the oil storage area, and the garage and machine shop facilities. Where potential problems exist, the location of lagoons, ponds and storage areas on fine-grained till and, in some cases, the addition of a reworked clay base or other form of lining should serve to reduce or eliminate the potential problem.

Both the coal piles and sewage lagoon will probably be minor potential sources of contamination. In the case of spray irrigation of the sod farm with sewage effluent, nitrate is the most likely constituent that could cause ground water contamination. In most instances, however, concentrations of nitrate will be well below 10 mg/L so that the operation of a sod farm is believed to be viable from the standpoint of ground water contamination. The garage and machine shop effluent could be a major hazard to ground water because of contamination from spilt or leaking gasoline and lubricant oils. Such contamination is a widespread ground water degradation factor in Canada and the United States. Thus, storage facilities for bulk fuels and lubricants should probably be above ground and located and designed so that the effects of spillage or leakage are minimized.

Mine dewatering is another potential contamination source for the ground water resources. Mathematical modelling of ground water flow patterns indicates that as mining operations approach Fife Lake, seepage from the lake will increase, and the result will possibly be increased boron concentrations in the ground water discharged from the mine dewatering wells. The water from the dewatering wells will flow into Girard Creek and then into Cookson Reservoir, where it may infiltrate the ground water system.

7.3.3 Transboundary Effects Due to Influences of The SPC Plant on Ground Water

The ground water investigation revealed that the SPC power plant, as originally planned, could degrade the quality of ground water in and around the plant area. No transboundary

quality effects are expected, however, because the direction of ground water flow at the International Boundary is parallel to the boundary and towards the East Poplar River. The most severe potential effect on ground water quality would be due to the ash lagoon. Leakage to ground water from ancillary facilities such as coal piles, the sewage lagoons, and sod farm maintenance operations might also have an effect. Other ground water related contamination problems could originate in the spoil areas due either to natural drainage to Girard Creek during the low-flow periods or to forced drainage resulting from dewatering. Leakage from the ash lagoons will have, by far, the greatest transboundary effects on the ground water.

7.4 Effects of Present and Future Uses on Water Quality

The Board has presented its conclusions regarding the boundary water quality objectives necessary to protect present and reasonably foreseeable uses in Chapter 4. In Sections 7.2 and 7.3, the various factors of the SPC development which could contribute to the degradation of the Poplar River system were described, and examples were given to illustrate the effects of that development on the water quality at several points in the Poplar River system, including at the International Boundary directly downstream from Cookson Reservoir.

For a complete summary of all predicted effects on the water quality of the Poplar River system, the reader is referred to Appendix A. A comparison of those effects with the objectives proposed by the Board shows that the two-unit SPC development at Coronach, as presently proposed, will adversely affect future uses by causing undesirable increases in concentrations of boron and TDS in portions of the river system. In reaching this conclusion, the Board has assumed full implementation of the provisions for apportionment.

From the information presented, the Board has concluded that the SPC development at Coronach will produce no other water quality effects which would adversely affect present and foreseeable uses in the Poplar River system.

The Board has also determined that adverse effects on biological habitat, particularly in the East Poplar River, could result from implementation of the recommended water quality apportionment provisions, unless releases of water are made during the spring runoff period which will scour the river bed sufficiently to inhibit growth of undesirable vegetation. The specific requirement is described in Section 4.3.

7.4.1 Boron

Predicted median values of boron concentrations at the International Boundary, with two units of the SPC Coronach plant in operation, with full water quality apportionment in effect, and with Canadian usage at the expected year 1985 level, are summarized below (see also Table 7.5):

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Boron (mg/L)	11.5	10.9	6.4	5.4	6.8	7.3	8.1	8.6	8.3	7.0	7.7	9.6

Alfalfa is the principal crop irrigated. The effects of boron in the irrigation water are not well understood, though the best available information to the Board (Section 3.1.3.2) suggests that, conservatively, 5.5 mg/L is a safe upper limit to avoid yield decreases in alfalfa crops.

The magnitude of the effects on alfalfa yields by the boron concentrations predicted as a result of the two-unit SPC development cannot be estimated with confidence. Median values of 8.1 mg/L at the International Boundary in July (Table 7.5) could reduce yields in the region between there and the confluence of the East Poplar and the Poplar rivers by as much as 6 percent (Section 3.1.3.2). The total acreage of irrigated alfalfa in this region is about 65 acres. Based upon 1978 estimates of crop value of $250 per acre, the estimated loss is about $15 per acre. South of the confluence of the East Poplar and the Poplar rivers, boron concentrations are expected to be diluted below 5.5 mg/L, and losses in alfalfa crop yield should not occur.

Barley is one of the crops most sensitive to boron in irrigation water. It has been noted (Section 3.1.3.2) that crop yields would be restricted by naturally occurring concentrations of boron in the Poplar River system. The Board has determined, however, that irrigated barley has been grown only sporadically in the Poplar River basin, and apparently never in the East Poplar subbasin between the International Boundary and Scobey, Montana. In 1978, one plot of 45 acres was grown on the Poplar River, just south of Scobey. If barley should be grown again at the same location just south of Scobey, the Board estimates that the net loss would be zero ($0.00) and $10 per acre (1978 dollars) respectively, for boron concentrations of 2 and 5 mg/L at the International Boundary on the East Poplar River (Appendix D). This predicted net loss would be the loss due to an increase in boron concentrations over natural conditions.

The Board has noted that there is an option open to farmers to produce additional acreage of barley in the future, though there is no evidence that this is planned. The fact that conditions are not naturally conducive to barley production is probably a factor.

The Board has also noted that, if irrigation practices change in the future due to limitations in the supply of water available, the leaching fraction could also change, thus increasing the adverse effects of boron on both barley and alfalfa. The Board cannot estimate with confidence what this change in effects would be although it notes that a change in leaching fraction from 0.3 to 0.2 could require a change in the objective for boron at the International Boundary on the East Poplar River from 6 mg/L to about 5 mg/L.

7.4.2 Total Dissolved Solids

'redicted median TDS concentrations at the International Boundary, with two units of the SPC Coronach plant operating, with full apportionment in effect, and with Canadian use of water at the expected 1985 level, are summarized below, (see also Table 7.4):

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
TDS (mg/L)	1090	1080	990	950	970	1010	1010	1050	1050	1060	1060	1090

At predicted future development levels (years 1985 or 2000), surplus water will not generally be available to overcome the build up of salts in those soils under irrigation. When this occurs, TDS increases will generally cause a yield reduction which can be estimated either by assuming less land will be irrigated with slightly more water, or by assuming projected irrigation development levels are reached, but with a slight yield reduction. Because there are fewer uncertainties in assuming yield reductions, the latter approach was used.

Table 3.8 contains estimated yield losses of irrigated alfalfa crops due to each of several median values of TDS at the International Boundary on the East Poplar River during the irrigation season. Assuming a leaching fraction of 0.30, it is noted that the SPC development will not adversely affect alfalfa crop yields downstream. However, as pointed out previously, future water demands could result in reduced quantities of water per application, thus decreasing the available leaching fraction. From Table 4.2 (assumed leaching fraction of 0.10) it is seen that predicted effects of the SPC development would then result in alfalfa crop yield losses downstream under those conditions. With no mitigation of the effects predicted to arise from the SPC operation, the Board estimates that a reduction in yield of between 2.7 and 1.5 percent may occur between the International Boundary and Scobey, Montana. This reduction in yield will be about 1 percent at the northern boundary of the Indian Reservation, becoming progressively less towards the mouth of the river. If, however, an impoundment is developed on the Reservation to permit future irrigation, the expected crop yield reduction would then remain about 1 percent throughout the Reservation. It should be noted that under natural conditions (TDS of 674 mg/L in the East Poplar River at the International Boundary) and assuming a leaching fraction 0.1 as used in Table 4.2, crop yield reductions of 0.8 percent would occur at Scobey, and of 0.1 percent at the northern boundary of the Indian Reservation.

The Board was advised by its Uses and Water Quality Objectives Committee (Appendix D) that an analysis of positive effects of the proposed apportionment of waters in this system had also been performed. Although the Committee could not reach agreement as to the validity of comparing that analysis with the predicted negative effects of the SPC development, the Board decided to provide the analysis as information which the Commission might find relevant.

The basis for the analysis is the fact that the storage of water for the SPC development could enable releases to be made for additional irrigation of crops downstream. It was estimated that, despite the negative effects of elevated concentrations of TDS and boron, a net positive yield would occur due to late season irrigation. On the other hand, it is possible that the Apportionment Task Force considered the positive effect of demand releases in developing an equitable allocation between countries. If this is true, a reiteration of those positive effects here would result in these benefits being considered twice. This is discussed in Appendix D.

The Board has not taken the position that these positive effects necessarily counterbalance the negative effects, inasmuch as it was unable to perform a complete evaluation of costs and benefits related to the SPC development and the proposed apportionment.

8. EFFECTS OF OTHER FORESEEABLE DEVELOPMENTS ON WATER QUALITY

The effects of development in Saskatchewan on water quality are discussed in Chapters 5, 6, and 7; however, the Board recognizes that future Montana development may also have an impact on Poplar River water quality. These potential Montana developments may include both industrial and irrigation water use.

8.1 Industrial Use

Coal and potash deposits are present in the Montana portion of the basin. However, the U.S. Bureau of Mines has described these coal deposits as nonstrippable. Consequently coal development is not a reasonably foreseeable development. On the other hand, development of potash reserves has received more interest. The Farmers Potash Company has begun preliminary work towards development of a potash mining facility in the Poplar River basin. The company has submitted a water permit application to the Montana Department of Natural Resources and Conservation for a reservoir with a capacity of 8650 dam^3 on the East Poplar River near Scobey.

The possible water quality effects of this proposal were not considered by the Board for the following reasons:

1) it is impossible to predict water quality impacts without data on the location and size of the development, detailed information on processes to be used, and resulting waste discharges;

2) it is likely that sufficient water for this development cannot be obtained from Poplar River basin surface water; and

3) the Montana Major Facility Siting Act and Pollution Discharge Elimination System will probably eliminate adverse impacts on surface or ground water quality.

8.2 Irrigation Use

Reasonably foreseeable water uses in Montana are described in Section 3.1.2. Evaluation of the impact on water quality by projected development in Montana is based on the same type of analysis used to evaluate existing uses in Section 3.1.4. As indicated in that section, the water quality model used by the Surface Water Quality Committee did not predict water quality parameter concentrations when estimated streamflow falls below .0142 m^3/s (0.5

cfs). The increased depletions caused by projected Montana development result in many estimated flows being less than .0142 m^3/s (0.5 cfs) at downstream points in the basin. Consequently, a complete analysis as presented in Section 3.1.4 is not possible for projected Montana development.

Because of a paucity of data, a number of assumptions were made in modelling surface water quality. One of the model assumptions was that irrigation return flow water had the same TDS concentration as ground water. Additional calculations were also made, however, in which all salts carried to the soil in the applied water were assumed to be removed by the return flow irrigation water. Assuming that one-third of the applied irrigation water returns to the stream, this would result in a threefold increase in salt concentration in the return irrigation water as compared to that in the applied irrigation water. Maximum increase in TDS concentration occurs in the winter months when flow is low. Thus, this impact does not occur during the irrigation season. The point to be made is that increased irrigation in Montana could result in higher TDS concentrations in surface water. Also, if impoundments are constructed on the lower Poplar River, the increased TDS concentrations in this return irrigation flow water could increase the salt concentrations in the impounded water.

Some effects of future water use in Montana on TDS and boron in four reaches of the Poplar River and tributaries are described below (see Figure 3.2 for schematic of Poplar River basin).

8.2.1 West Poplar River

8.2.1.1 Streamflow

Increased development in Montana as projected would significantly decrease streamflow in the West Poplar River. For example, mean flows in June, July, August and September would be reduced by 22, 95, 83 and 83 percent respectively. Return flows due to increased irrigation development would be expected to increase streamflow in January, February, October, November and December.

8.2.1.2 Total Dissolved Solids and Boron

During the non-irrigation season, TDS concentrations are not expected to change significantly if the projected development in Montana is implemented. However, during the months of July, August and September the predicted streamflows reflect substantial depletion by additional irrigation development, and TDS levels can also be expected to increase significantly.

Because boron seems to be derived almost entirely in Canada, increased stream depletions due to additional irrigation in Montana will increase boron concentrations through a reduction in dilution water. This concentration increase would probably not be significant.

8.2.2 Upper Poplar River (Above confluence with the East Poplar River)

8.2.2.1 Streamflow

Increased development in Montana as projected would significantly decrease streamflow in the upper Poplar River. For example, mean flows in June, July, August and September would be reduced by 15, 30, 50 and 80 percent respectively. Return flow due to increased irrigation development is expected to increase streamflow in October, November, December and January.

8.2.2.2 Total Dissolved Solids and Boron

During the non-irrigation season, TDS concentrations are not expected to change significantly if the projected development in Montana is implemented. However, during the months of August and September, the predicted streamflows will undergo substantial depletion by additional irrigation development and TDS levels can also be expected to increase substantially.

Impacts on boron concentrations as given for the West Poplar River also apply to this subbasin.

8.2.3 East Poplar and Lower Poplar Rivers

8.2.3.1 Streamflow

The relatively small amount of development expected to occur in the Montana portion of the East Poplar River basin would not appreciably impact on water quality characteristics of that stream.

Projected Montana development would seriously deplete the Poplar River at Poplar, Montana. Mean flows would be reduced to zero in five months of the year (January, February, October, November and December). Flows in June, July, August and September would be reduced 63, 65, 71 and 72 percent respectively.

8.2.3.2 Total Dissolved Solids

TDS concentrations can be expected to increase substantially in the lower Poplar River if future Montana development occurs as projected in Section 3.1.2.

8.2.3.3 Boron

During summer months, boron concentrations can be expected to increase slightly, perhaps 10 percent, in the lower Poplar River.

9. SUMMARY OF EFFECTS

In its Directive to the Board, the International Joint Commission requested a report on the effects on water quality and uses (existing and reasonably foreseeable) of changes in flow due to Poplar River apportionment, the development at Coronach, and other foreseeable developments in either country, both separately and cumulatively (Section 1.4). Significant impacts of the Coronach development on the surrounding aquifers were also to be addressed by the Board. Sections 5.2, 6.3, 7.4, and 8, contain the Boards findings on present and predicted effects. These are summarized as follows:

9.1 Water Quantity Apportionment

The Board has determined that implementation of apportionment recommendations regarding flow releases from Cookson Reservoir could result in damage to the biological habitat of the East Poplar River unless specified releases are made. The Board has defined the release requirements on the basis of long-term (10 year) averages.

Adverse impacts on the biological resources due to water quantity apportionment could be substantial in the East Poplar River because of changes to the hydraulic characteristics of the stream channel. Habitat conditions in the East Poplar River have historically been marginal for aquatic life, and thus the subbasin is sensitive to perturbations caused by flow regime changes. The Board recognizes that fish and waterfowl are not as abundant in the Poplar River drainage as in other areas in Montana. To local residents, however, the local biological resources have considerable value.

The Board has found no rationale for estimating direct water quality effects resulting exclusively from apportionment. The Board has assessed the differences between 1) water quality effects to be expected with the operation of a two-unit SPC plant at Coronach, utilizing water necessary only for that operation plus other foreseeable uses in Canada, and 2) effects of the operation of that plant and the consumptive use of all Canada's apportioned share of Poplar River system water. These differences were not significant.

9.2 SPC Power Project

The Board has determined that the only significant direct surface water quality effects of the operation of a two-unit plant at Coronach, under conditions of apportionment, will relate to increased concentrations of boron and TDS in the downstream waters.

The Board also determined that the predicted increase in concentrations of boron will adversely affect yields of alfalfa being irrigated with water from the East Poplar River. This presently amounts to about 26 ha (65 ac) located in the region between the International Boundary and the confluence of the Poplar and East Poplar rivers.

The predicted increase in concentrations of boron will, in the opinion of the Board, adversely affect yields of barley being irrigated with water from the East Poplar River and downstream. In 1978, this amounted to 18 ha (45 ac) of barley located just south of Scobey, which is not being committed to barley in 1979, although another small acreage of barley will be grown in that same vicinity. These sporadic instances of irrigation of barley probably do not achieve maximum yield under natural conditions due to the presence of boron, and would be expected to suffer additional yield decrease due to the SPC development.

There is no basis upon which to estimate future increases in barley acreage requiring irrigation with affected waters. However, projected future acreages which will be irrigated in the East Poplar River subbasin are estimated to be 40 and 90 ha (95 and 225 ac) by the years 1985 and 2000 respectively, but alfalfa is expected to remain the principal crop (Table 3.2).

The predicted increase in concentrations of TDS will, in the opinion of the Board, adversely affect yields of alfalfa being irrigated with water in the portions of the Poplar River system downstream from Coronach if increased demands for water result in more stringent irrigation practices. Increased yield losses, on the average, will vary between zero and just less than 3 percent, depending upon the location of the crops, without measures to mitigate the effects of Cookson Reservoir and the two-unit SPC plant.

The Board has determined that there will be increased acreage of alfalfa irrigated with affected waters. The bulk of this increase is predicted to be within the Fort Peck Indian Reservation, after construction of an impounding reservoir. The effect of that new reservoir is expected to be a slight reduction in TDS concentrations during the irrigation season.

Although the effect of the SPC plant will be to elevate TDS concentrations, the net effects of the plant, water quantity apportionment, and the local impoundment are expected to increase crop yields on the reservation.

The effects of boron on future alfalfa production upstream from the Fort Peck Reservation could become more severe due to a change in irrigation practices, if less water is used per application (Section 3.1.3.2). The Board was unable to determine the significance of this change, although the rate of change of yield reduction due to boron, illustrated in Table 3.6, suggests that crop yield decreases might not be substantially higher than those expected under present irrigation practices.

9.3 Other Foreseeable Developments

The Board has determined that the only foreseeable development in either country which could alter the effects predicted in Sections 9.1 and 9.2 relates to the possible added contributions of TDS and boron to the river system from increased irrigation in Montana.

9.4 Ground Water

The effects of the SPC operation at Coronach on ground water are expected to be manifested in two ways: 1) dewatering, which will lower the water table; and 2) the storage of water in Cookson Reservoir, which will elevate the adjacent water table. The maximum water level decline in Montana is expected to occur at the International Boundary and amount to about 0.7 m (2.3 ft) at the termination of the mining operation, 35 years after commencement. The maximum expected elevation in Montana due to the reservoir will also occur at the International Boundary, and will amount to 0.1 m (4 in) near the East Poplar River. The most serious adverse effects to the quality of the ground water which could affect uses are related to seepages from the ash lagoons. This source is, in part, accounted for in evaluations of surface water impacts, as much of the seepage from the ash lagoons is expected to enter the river system.

10. MITIGATION

10.1 Measures and Alternatives

Chapter 9 contains a summary of the Board's findings respecting effects of the proposed two-unit SPC plant at Coronach, its ancillary operations, and proposed apportionment of the waters of the Poplar River system. It has been pointed out that adverse direct water quality effects arise only as a result of increased concentrations of boron and TDS. The proposed developments will not present new problems, but will aggravate existing ones.

The prevention of any additional and future adverse effects would require maintenance of boron and TDS concentrations at natural levels. Because the effects are of varying significance, and because water quality will also be influenced by increased development in Montana, the Board decided to present a set of alternatives for mitigation, describing for each the cost and downstream consequences which are expected to ensue.

The measures include construction changes as well as changes in water management and operating procedures. The Board does not include under mitigation such measures that are entirely compensatory over either the short or the long term. A complete discussion of mitigation is found in Appendix E.

The following mitigation measures are expected to provide acceptable quality of transboundary flow in the East Poplar River:

(1) The ash disposal alternatives shown in Table 10.1 present various levels of reduction of TDS and boron in the East Poplar River at the International Boundary. Alternatives 2,3,5,6, and 7 involve, in each case, a lower expenditure for the consolidated till lining and a higher expenditure for a more effective lining. There remains some doubt as to the exact reduction in seepage that can be achieved with different lagoon lining methods.

    Alternatives 4,8 and 9, using dry flyash disposal, are considered to be most effective in minimizing water quality problems as well as reducing uncertainties with seepage rates.

If a lagoon option is selected, sufficient information should be provided with the final design to demonstrate with reasonable assurance that the selected seepage control provisions will keep seepage rates within the limits of 5 L/s to the East Poplar River below Morrison Dam. If reasonable assurance cannot be provided that these limits will not be exceeded, the lagoons should be relocated north of the plant and reservoir.

Table 10.1 ESTIMATED ANNUAL COST OF MITIGATION (2 UNITS)

MEAN/MAXIMUM MAY TO SEPTEMBER CONCENTRATION IN THE EAST POPLAR RIVER AT INTERNATIONAL BOUNDARY (46 YEAR PERIOD)		MITIGATION MEASURES	ESTIMATED ADDITIONAL ANNUAL COST[1]	
TDS	BORON		DOLLARS	PERCENT OF TOTAL PROJECT[2]
Proposed System				
1) 953/1795	8.1/18.7	Proposed ash disposal system (once-through lagoon)	0	0.00
Primary Mitigation (Ash Disposal)				
2) 953/1795	1.8/2.5	Proposed ash disposal system with boron removal from decant	623,960 - 1,595,550	0.94 - 2.41
3) 961/1754	2.9/5.6	Combined ash recirculating lagoon	87,720 - 645,880	0.13 - 0.97
4) 963/1655	1.7/3.1	Dry flyash/dewatered bottom ash	1,128,060	1.70
Supplemental Mitigation (Ash Disposal plus Additional TDS Reduction)				
5) 853/1375	2.9/5.4	Combined ash recirculating lagoon, lime softening of Cookson Reservoir	405,100 - 963,260	0.61 - 1.45
6) 825/1218	2.1/3.1	Combined ash recirculating lagoon, water storage on Poplar River	194,670 - 752,830	0.29 - 1.14
7) 733/1300	2.2/4.1	Combined ash recirculating lagoon, water storage above Cookson Reservoir	154,560 - 712,720	0.23 - 1.07
8) 825/1218	1.7/3.1	Dry flyash/dewatered bottom ash, water storage on Poplar River	1,235,010	1.86
9) 733/1300	1.7/3.1	Dry flyash/dewatered bottom ash, water storage above Cookson Reservoir	1,194,900	1.80

[1] The two cost figures listed are for the proposed ash lagoon lining and an improved lining. If under drainage is provided, the improved lining costs may be higher than listed.

[2] Base annual cost of total project (2 units) used in computations is $66,300,000.

(2) Maintenance or reduction of TDS to 1000 mg/L or less can be achieved by two mitigation alternatives. One alternative involves water treatment, whereas the other alternative depends upon dilution. The first would be the installation and operation of a reservoir water softening facility (Alternative 5). The second TDS mitigation alternative is the construction of a storage and diversion reservoir on either the Poplar River or the East Poplar River upstream of Cookson Reservoir (Alternatives 6, 7, 8 and 9). There are, of course, numerous other possible combinations of facilities (Appendix E).

(3) The power plant waste management system should be designed in conjunction with the selected ash disposal option to provide containment and treatment for all waste waters before release to Cookson Reservoir.

(4) The quantity of water produced by mine dewatering should be minimized and suitable control practices and procedures should be adopted for diverted runoff and non-point source discharges.

(5) Planned outages of the power plant should be scheduled during those months of highest evaporation loss.

(6) Facilities should be provided to control overflows from Fife Lake so that no significant deterioration of water quality will occur in Cookson Reservoir. These should also be operated in such a way as to prevent flooding around the lake.

(7) The following measures may be taken to reduce the effects of developments on the biological resources in the East Poplar River drainage basin in the United States:

(a) within the provisions of the recommended water quantity apportionment agreement, releases of water to the East Poplar River should be made in accordance with requirements as defined in Section 4.3; and

(b) if a reservoir is constructed on the Poplar River in Canada, releases should be regulated appropriate to maintain the aquatic habitat in the United States.

10.2 Costs

The annual cost of the proposed SPC mitigation (electrostatic precipitator, lagoons with rolled till lining, and decant into Cookson Reservoir) is $1,708,860. The estimated annual costs associated with the mitigation of ash disposal, additional to those for the proposed SPC system, are shown in Table 10.1. These cost estimates were made in early 1979 and reflect material and labor demands at that time.

11. SURVEILLANCE

A surveillance program is necessary to determine impacts from water quantity apportionment or Canadian development on the quality of surface or ground water crossing the International Boundary. Because of the dynamic nature of the development and the incomplete and changing nature of the scientific data base used to set water quality objectives and to determine impacts, the surveillance program should be periodically reviewed.

All sample collecting, handling, and analysis should be done uniformly using techniques mutually acceptable to both Canada and the United States. All agencies involved in this program should participate in an effective, formal, quality control program.

11.1 Surface Water Surveillance

The surface water quality objectives in this report were determined in part by consideration of the effects of downstream changes in water quality. Therefore periodic sampling should be done at locations below the International Boundary. Because there are significant diurnal changes in temperature, dissolved oxygen and pH, these parameters should be measured over several 24 hour periods.

Suggested surface water sample location sites, frequency of sampling, and analyses are given in Table 11.1.

11.2 Ground Water Surveillance

Recommended ground water surveillance includes monitoring of dewatering rates, ground water levels and changes in ground water quality. This would provide adequate warning of significant changes in the ground water quantity and quality resulting from SPC activities. It would also assist in the verification of the two ground water simulation models used in this study.

Discharge rates for all dewatering wells should be regularly measured and recorded and compared, with estimated rates used to predict ground water level changes resulting from the SPC power plant operation. Persistent major deviations from the predicted dewatering rates would tend to invalidate model predictions.

Table 11.1 SUGGESTED PARAMETERS SAMPLE SITE LOCATIONS AND FREQUENCY OF SAMPLING

Parameters	Sample Site Location	Sampling Frequency
Aluminum	Boundary Stations	Monthly
Ammonia	Boundary Stations	Monthly
Boron	Boundary Stations, plus[1]	Monthly, plus[1]
Cadmium	Boundary Stations, plus[1]	Monthly, plus[1]
Chromium	Boundary Stations, plus[1]	Monthly, plus[1]
Copper	Boundary Stations, plus[1]	Monthly, plus[1]
Fluoride	Boundary Stations, plus[1]	Monthly, plus[1]
Iron	Boundary Stations, plus[1]	Monthly, plus[1]
Lead	Boundary Stations, plus[1]	Monthly, plus[1]
Manganese	Boundary Stations, plus[1]	Monthly, plus[1]
Mercury	Boundary Stations, plus[1]	Monthly, plus[1]
Nitrate	Boundary Stations, plus[1]	Monthly, plus[1]
Dissolved Oxygen	Boundary Stations, plus[2]	Monthly, plus[2]
pH	Boundary Stations, plus[2]	Monthly, plus[2]
Sulfate	Boundary Stations	Monthly
Temperature	Boundary Stations, plus[2]	Continuous, plus[2]
Specific Conductance	Boundary Stations, plus[1]	Continuous, plus[1]
Total Dissolved Solids	Boundary Stations	Monthly
Common Ions	Boundary Stations	Monthly
Zinc	Boundary Stations	Monthly
Fecal Coliform Bacteria	Boundary Stations	Monthly
Total Coliform Bacteria	Boundary Stations	Monthly

[1]Should include at least one synoptic survey, during July or August, at the International Boundary stations and near Scobey on the Poplar and East Poplar River and the Poplar River near the Fort Peck Indian Reservation Boundary.

[2]Should include at least two diurnal sampling periods during low water in July or August.

Ground water levels and chemical analyses should be determined and recorded regularly in selected wells in that part of the East Poplar River basin lying to the south of the SPC power plant development, to the west of the East Poplar River and extending into northern Montana. Monitoring over most of this area would be intended for the identification of water level declines due to dewatering and for observation of any growth in the area affected by such declines. Ground water levels and chemical constituents should be measured in the vicinity of Cookson Reservoir and the ash lagoons to determine increases due to the effects of these features.

MINORITY REPORT
INTERNATIONAL POPLAR RIVER
WATER QUALITY BOARD

June 29, 1979

Submitted by:

Abe Horpestad, Board Member, and
Member of the Surface Water Quality,
and Uses and Objective Committees

I am submitting this report based on a rough final draft of the Board report. Thus, in most cases, I shall not refer to specific page or section numbers. Although, in general, I agree with the Board and Committee reports, I feel I must submit this minority report for the following reasons:

1. minority committee reports were not discussed in the Board report;
2. only crop yield decreases and the crops grown at present were considered;
3. the effects of boron and TDS on crop yields are not well understood;
4. the Board's report implies that some damage is acceptable; and
5. to present an alternative to extensive mitigation by Saskatchewan Power Corporation.

1. "Minority committee reports were not discussed in the Board report"

"Recommended criteria at the International Boundary Poplar River Basin" submitted by Mike Watson.

The values listed as historic measurements for the East Fork at the International Boundary on page 12, are nearly all taken after the construction of Morrison Dam and thus should not be considered historic values. The data listed in columns entitled, "Poplar at Boundary" and "West Poplar at Boundary" on page 15, are simulated flow weighted median values for the 43 years of flow and are apparently compared to instantaneous values for two years. Actually, the simulated values compare fairly well with the measured values when the measured values were obtained at flows in excess of 0.5 cubic feet per second (cfs). Because of ground water influences, the model cannot be used for TDS concentrations at flows less than 0.5 cfs. The first two values in the column "Poplar at Boundary" on page 15, are based on less than ten values. That is, for 33 out of 34 years of flow records, the median flow in January and February was less than 0.5 cfs. Similarly for the last 4 numbers in the "West Poplar at Boundary" column.

The values in the column headed "Historic Salinity" on page 18, Table 3, are in error. They imply that, at a flow of 100,000 cfs, the TDS concentration would be about 600 milligrams per litre. Available records indicate that at1,000 cfs the TDS will be about 100 mg/L. The data from which this relationship was derived apparently consisted mainly of flow and TDS values obtained after construction of Morrison Dam. Even if these data are used, I cannot derive the relationship shown. If data before the dam was constructed are used, the values would be:

CFS	TDS (mg/L)
5	707
10	523
50	264
100	198
500	107
1,000	83

These values are monthly flow weighted values derived using the regression equations given in Appendix A. The "Historic" values in Table 4 are also incorrect. The correct values are:

CFS	TDS (mg/L)
1	779
5	660
10	614
50	518
100	481

These are also simulated flow weighted median values derived using the regression equations in Appendix A of the Board's report. If these "corrected" values were used it would result in lower recommended boundary salinity values in Tables 3 and 4.

Watson's minority report does not mention that storage would be required in order for appreciable increases in irrigation to occur on the reservation. The effect of storage would be to decrease the effects of Canadian development on TDS concentrations on the reservation.

The Committee Minority report titled "Minority Report with Respect to the Recommended Boron Objective, Poplar River Basin", will not be discussed here as I helped draft it and am covering the same point in section 4.

2. "Only crop yield decreases and the crops grown at present were considered"

Only the effects of TDS and boron concentration increases are apparently mentioned in the report. It should be emphasized that subsidiary costs, in addition to yield decreases, are caused by increasing concentrations of boron and TDS. These additional costs are difficult to quantify. This does not mean they are not real. Increasing boron and to a lesser extent TDS concentrations will limit the crops that can be grown. For example, in 1979, wheat, oats, and alfalfa are being grown on several of the parcels previously used for barley. It is probable that barley and other crops will be irrigated in the future, if the water quality permits. This type of information is difficult if not impossible to quantify. Nevertheless, the Board's report should have emphasized this probability and perhaps noted some of the relative tolerances of possible crops. I say perhaps, because data comparing relative tolerances of crops such as safflower, and rape are apparently very limited (and perhaps of doubtful validity).

The Board's report should also have noted that the cost of any yield decrease is of necessity taken from the profit margin of the crop and thus a small yield decrease may be relatively significant.

3. "The effects of boron and TDS on crop yields are not well understood"

Available data on the effects of boron concentrations on crops commonly irrigated in the Poplar River basin are limited to alfalfa, oats and barley. The most complete work was done by Eaton in 1944*. Eaton's data for the effects on some crops are given in Table 3.6 of the main report. These data indicate that any increase above natural levels will cause decreases in barley yields. Eaton's reported data for alfalfa were based on a one year experiment. They show that the concentration in the roots after one growing season is higher at higher levels of applied boron. Because this experiment was terminated after one growing season while alfalfa plants commonly persist for several growing seasons (five to seven in Montana) this experiment does not enable a determination of the effects of increasing boron concentrations on long-term production of alfalfa. In searching the literature, no pertinent data were found which enable resolution of this problem. From an examination of the literature, it appears that the safe levels listed in the literature are all derived from Eaton's work in 1944. Thus, the so-called safe values in the literature are all based on work which has a serious flaw.

In spite of the poor scientific data base, I believe that there are two factors which indicate that the values in the Board's report are probably safe for short-term alfalfa production:

a) use of Eaton's data leads to a value of 7.5 mg/L in irrigation water as a safe value; thus, a considerable safety margin is built in at 5.5 mg/L.

b) the predicted high concentrations of boron will not occur for some tens of years because of delays in the passage of boron rich waters seeping from the ash lagoons to the East Poplar River below Morrison dam. These waters are the major source of boron.

However, because of the unresolved problem of boron accumulation in the roots of alfalfa, and because barley production and possibly other crops will definitely be affected by increasing boron concentrations, I suggest that research be initiated as soon as possible to resolve the questions about the effects of boron on alfalfa and other crops. This should be done jointly by the United States and Canadian Governments, in the area, and should extend over at least three growing seasons.

The data used to predict the effects of increasing TDS concentrations on crop yields are also not good. In this case, the problem is caused by using the observed effects of large TDS increases to predict the effects of small TDS increases. I feel

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* Eaton, F.M., 1944. Deficiency toxicity and accumulation of boron in plants.

that the predicted effects of increasing TDS concentrations on crop yields are poor and quite likely substantially in error. Thus, I suggest that the effects of increasing concentrations on crop yields be investigated jointly with the effects of boron.

4. "The Board's report implies that some damage is acceptable"

   This implication is given because the Board's report lists the relative costs for mitigation and the costs resulting from yield decreases in Montana. This naturally leads one to an evaluation of the costs vs. the benefits. However, in this case, the costs and benefits do not accrue to the same populations. Thus, I feel that any comparison of the costs and benefits is wholly inappropriate. While the relative yield decreases are small in comparison to the mitigation costs required to prevent these decreases, the decreases nonetheless are important to the individuals affected and are perhaps underestimated, unless one realizes that the yield decreases and the monetary costs incurred thereby must come out of the profit margin normally present and, in many cases, may make new irrigation projects infeasible.

   Thus, I personally feel that, based upon the effects and my amateur interpretation of the Boundary Waters Treaty, the only objectives that can be reasonably set if compensation is not considered, are at the present water quality.

5. "An Alternative to Extensive Mitigation by Saskatchewan Power Corporation"

   The Board's and Committees' reports indicate that health hazards will not be caused by the Saskatchewan Power Corporation's aquatic discharge. They also indicate that the projected high levels of boron will not occur for some time. The Board's report also documents the fact that the costs of mitigation are relatively large and the costs resulting in Montana from elevated TDS and boron concentrations are relatively small. Thus, I believe that, even though the costs and benefits are on different sides of the International Boundary, the only reasonable course is for Saskatchewan Power to directly reimburse the individuals in Montana for the actual damages suffered. This would be based on the suggested local research on the effects of increased concentrations and documented achieved yields. Documentation of other costs incurred would be difficult, but I believe such documentation is possible.